इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS/IEC 62271-203 (2003): High-Voltage Switchgear and Controlgear, Part 203: Gas-Insulated Metal-Enclosed Switchgear for Rated Voltages Above 52 kv [ETD 8: High Voltage Switchgear and Controlgear]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

BLANK PAGE

BRUTUM FULMEN

IGNORANTIA JURIS NON EXCUSAT

PROTECTED BY COPYRIGHT

भारतीय मानक

उच्च-वोल्टता के स्विचगियर और नियंत्रणगियर

भाग 203 52 किलोवाट से अधिक की रेटित वोल्टेज के लिए गैस-विद्युतरोधित धातु-संलग्न स्विचगियर

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 203 GAS-INSULATED METAL-ENCLOSED SWITCHGEAR FOR RATED VOLTAGES ABOVE 52 kV

ICS 29.130.10

© BIS 2008

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 2008

Price Group 15

High-Voltage Switchgear and Controlgear Sectional Committee, ETD 08

NATIONAL FOREWORD

This Indian Standard (Part 203) which is identical with IEC 62271-203 : 2003 'High-voltage switchgear and controlgear — Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the High-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

This standard is to be read in conjunction with IEC 60694 (2002) 'Common specifications for high-voltage switchgear and controlgear standards'.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60137 Insulating bushings for alternating voltages above 1 000 V	IS 2099 : 1986 Bushings for alternating voltages above 1 000 volts (*second revision*)	Technically Equivalent
IEC 60694 (2002) Common specifications for high-voltage switchgear and controlgear standards	IS 12729 : 2004 Common specifications for high-voltage switchgear and controlgear standards	Identical
IEC 62271-102 (2001) High-voltage switchgear and controlgear — Part 102: High-voltage alternating current disconnectors and earthing switches	IS/IEC 62271-102 : 2001 High-voltage switchgear and controlgear: Part 102 High-voltage alternating current disconnectors and earthing switches	do

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60044-1	Instrument transformers — Part 1: Current transformers
IEC 60044-2	Instrument transformers — Part 2: Inductive voltage transformers
IEC 60068-2-11	Environmental testing — Part 2: Tests, Test Ka: Salt mist
IEC 60141-1	Tests on oil-filled and gas-pressure cables and their accessories — Part 1: Oil-filled, paper or polypropylene paper laminate insulated, metal-sheathed cables and accessories for alternating voltages up to and including 500 kV

(*Continued on third cover*)

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 203 GAS-INSULATED METAL-ENCLOSED SWITCHGEAR FOR RATED VOLTAGES ABOVE 52 kV

1 General

1.1 Scope

This standard specifies requirements for gas-insulated, metal-enclosed switchgear in which the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure, for alternating current of rated voltages above 52 kV, for indoor and outdoor installation, and for service frequencies up to and including 60 Hz.

For the purpose of this standard, the terms "GIS" and "switchgear" are used for "gas-insulated metal-enclosed switchgear".

The gas-insulated metal-enclosed switchgear covered by this standard consists of individual components intended to be directly connected together and able to operate only in this manner.

This standard completes and amends, if necessary, the various relevant standards applying to the individual components constituting GIS.

1.2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Subclause 1.2 of IEC 60694 is applicable with the following additions:

IEC 60044-1, *Instrument transformers – Part 1: Current transformers*

IEC 60044-2, *Instrument transformers – Part 2: Inductive voltage transformers*

IEC 60068-2-11, *Environmental testing – Part 2: Tests. Test Ka: Salt mist*

IEC 60137, *Insulating bushings for alternating voltages above 1 000 V*

IEC 60141-1, *Tests on oil-filled and gas-pressure cables and their accessories – Part 1: Oil-filled, paper or polypropylene paper laminate insulated, metal-sheathed cables and accessories for alternating voltages up to and including 500 kV*

IEC 60840, *Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m = 170 kV) – Test methods and requirements*

IEC 60859, *Cable connections for gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above – Fluid-filled and extruded insulation cables – Fluid-filled and dry type cable-terminations*

IEC 61462, *Composite insulators – Hollow insulators for use in outdoor and indoor electrical equipment – Definitions, test methods, acceptance criteria and design recommendations*

IEC 61639, *Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

IEC 62067, *Power cables with extruded insulation and their accessories for rated voltages above 150 kV (U_m = 170 kV) up to 500 kV (U_m = 550 kV) – Test methods and requirements*

IEC 62155, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*

IEC 62271-100, *High-voltage switchgear and controlgear – Part 100: High-voltage alternating-current circuit-breakers*

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

ISO 3231, *Paints and varnishes – Determination of resistance to humid atmospheres containing sulfur dioxide*

NOTE Other standards are referred to for information in this standard. They are listed in the Bibliography.

2 Normal and special service conditions

Clause 2 of IEC 60694 is applicable with the following additions:

At any altitude the dielectric characteristics of the internal insulation are identical with those measured at sea-level. For this internal insulation, therefore, no specific requirements concerning the altitude are applicable.

Some items of a GIS such as pressure relief devices and pressure and density monitoring devices may be affected by altitude. The manufacturer shall take appropriate measures if necessary.

2.1 Normal service conditions

Subclause 2.1 of IEC 60694 is applicable, taking into the account Table 101 of this standard.

2.2 Special service conditions

Subclause 2.2 of IEC 60694 is applicable, taking into account Table 101 of this standard.

In case where higher than (>) is used in the table the value shall be specified by the user as described in IEC 60694

Table 101 – Reference table of service conditions relevant to GIS

Item	Normal		Special	
	Indoor	Outdoor	Indoor	Outdoor
Ambient air temperature:				
Minimum (°C)	–5 or –25	–25 or –40	–25	–50
Maximum (°C)	+40	+40	+50	+50
Solar radiation (W/m²)	Not applicable	1 000	Not applicable	>1 000
Altitude (m)	1 000	1 000	>1 000	>1 000
Pollution class [a]	Not applicable	II	II, III or IV	III or IV
Ice coating (mm)	Not applicable	1, 10 or 20	Not applicable	>20
Wind (m/s)	Not applicable	34	Not applicable	>34
Humidity (%)	95	100	98	100
Condensation or precipitation	Occasional	Yes	Yes	Yes
Vibration class	Not applicable	Not applicable	IEC 61166	IEC 61166
Induced electromagnetic disturbances in secondary system (kV)	1,6	1,6	>1,6	>1,6

NOTE The user's specification may use any combination of normal or special service conditions above

[a] Pollution class II, III and IV according to Table 1 of IEC 60815

3 Terms and definitions

For the purposes of this document, the definitions given in IEC 60694, together with the following definitions, apply.

3.101
metal-enclosed switchgear and controlgear
switchgear and controlgear assemblies with an external metal enclosure intended to be earthed, and complete except for external connections

[IEV 441-12-04]

3.102
gas-insulated metal-enclosed switchgear
metal-enclosed switchgear in which the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure

NOTE 1 This term generally applies to high-voltage switchgear and controlgear.

[IEV 441-12-05]

NOTE 2 Three-phase enclosed gas-insulated switchgear applies to switchgear with the three phases enclosed in a common enclosure.

NOTE 3 Single-phase enclosed gas-insulated switchgear applies to switchgear with each phase enclosed in a single independent enclosure.

3.103
gas-insulated switchgear enclosure
part of gas-insulated metal-enclosed switchgear retaining the insulating gas under the prescribed conditions necessary to maintain safely the highest insulation level, protecting the equipment against external influences and providing a high degree of protection to personnel

NOTE The enclosure can be single-phase or three-phase.

3.104
removable link
part of the conductor which can easily be removed in order to isolate two parts of the GIS from each other

3.105
compartment
part of gas-insulated metal-enclosed switchgear, totally enclosed except for openings necessary for interconnection and control

NOTE A compartment may be designated by the main component contained therein, e.g. circuit-breaker compartment, busbar compartment.

3.106
component
essential part of the main or earthing circuits of gas-insulated metal-enclosed switchgear which serves a specific function (for example circuit-breaker, disconnector, switch, fuse, instrument transformer, bushing, busbar, etc.)

3.107
support insulator
internal insulator supporting one or more conductors

3.108
partition
support insulator of gas-insulated metal-enclosed switchgear separating one compartment from other compartments

3.109
bushing
structure carrying one or more conductors at the terminal of the enclosure and insulating it therefrom, including the means of attachment (e.g. air bushings)

3.110
main circuit
all the conductive parts of gas-insulated metal-enclosed switchgear included in a circuit which is intended to transmit electrical energy

[IEV 441-13-02, modified]

3.111
auxiliary circuit
all the conductive parts of gas-insulated metal-enclosed switchgear included in a circuit (other than the main circuit) intended to control, measure, signal and regulate

NOTE The auxiliary circuits of gas-insulated metal-enclosed switchgear include the control and auxiliary circuits of the switching devices

3.112

design temperature of enclosures

maximum temperature that the enclosures can reach under specified maximum service conditions

3.113

design pressure of enclosures

relative pressure used to determine the design of the enclosure

NOTE 1 It is at least equal to the maximum pressure in the enclosure at the highest temperature that the gas used for isolation can reach under specified maximum service conditions

NOTE 2 The transient pressure occurring during and after a breaking operation (e g circuit-breaker) is not to be considered in the determination of the design pressure

3.114

design pressure of partitions

relative pressure across the partition

3.115

operating pressure of pressure relief device

relative pressure chosen for the opening operation of pressure relief devices

3.116

routine test pressure of enclosures and partitions

relative pressure to which all enclosures and partitions are subjected after manufacturing

3.117

type test pressure of enclosures and partitions

relative pressure to which all enclosures and partitions are subjected for type test

3.118

fragmentation

damage to enclosure due to pressure rise with projection of solid material

NOTE The term "no fragmentation of the enclosure" is interpreted as follows

- no explosion of the compartment,
- no solid parts flying off from the compartment

Exceptions are

- parts of the pressure relief device, if their ejection is directed,
- glowing particles and molten material resulting from burn-through of the enclosure

3.119

disruptive discharge

phenomena associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or almost zero

3.120

service period

time until a maintenance, including opening of the gas compartments, is required

3.121

transport unit

part of gas-insulated metal-enclosed switchgear suitable for shipment without being dismantled

4 Ratings

The ratings of GIS comprise the following:

a) rated voltage, equal to highest voltage for equipment (U_r);

b) rated insulation level;

c) rated frequency (f_r);

d) rated normal current (I_r) (for main circuits);

e) rated short-time withstand current (I_k) (for main and earthing circuits);

f) rated peak withstand current (I_p) (for main and earthing circuits);

g) rated duration of short-circuit (t_k);

h) rated values of the components forming part of gas-insulated metal-enclosed switchgear, including their operating devices and auxiliary equipment.

4.1 Rated voltage for equipment (U_r)

Subclause 4.1 of IEC 60694 is applicable with the following addition:

NOTE 1 Components forming part of the GIS may have individual values of rated voltage for equipment in accordance with the relevant standards

NOTE 2 For the purpose of this standard, the rated voltage (U_r) defined in IEC 60694 is rated voltage of equipment (U_r)

4.2 Rated insulation level

Subclause 4.2 and Tables 1 and 2 of IEC 60694 are applicable. Tables 102 and 103 below are the preferred values for GIS.

The GIS comprises components having a definite insulation level. Although internal faults can largely be avoided by the choice of a suitable insulation level, measures to limit external overvoltages (e.g. surge arresters,) should be considered.

NOTE 1 According to CIGRE studies the natural ratio between the withstand voltages under standard tests, for SF_6 gas insulation is U_d / U_p = 0.45 and U_s / U_p = 0.75. The values U_d shown in Table 103 are calculated with this factors.

NOTE 2 Regarding the external parts of bushings (if any), refer to IEC 60137.

NOTE 3 The waveforms are standardized lightning impulse and switching impulse shapes, pending the results of studies on the ability of this equipment to withstand other types of impulses.

NOTE 4 The choice between alternative insulation levels for a particular rated voltage for equipment should be based on insulation coordination studies, taking into account also the self-generated transient overvoltages due to switching.

Table 102 – Preferred rated insulation levels for rated voltages for equipment of range I

Rated voltage for equipment U_r kV (r.m.s. value)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s. value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-earth, across open switching device and between phases	**Across the isolating distance**	**Phase-to-earth, across open switching device and between phases**	**Across the isolating distance**
(1)	**(2)**	**(3)**	**(4)**	**(5)**
72,5	140	160	325	375
100	185	210	450	520
123	230	265	550	630
145	275	315	650	750
170	325	375	750	860
245	460	530	1 050	1 200

NOTE Values in column (2) are applicable

a) for type tests, phase-to-earth and between phases;

b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device.

Values in columns (3), (4) and (5) are applicable for type tests only.

Table 103 – Preferred rated insulation levels for rated voltages for equipment of range II

Rated voltage for equipment U_r kV (r.m.s. value)	**Rated short-duration power-frequency withstand voltage** U_d kV (r.m.s. value)		**Rated switching impulse withstand voltage** U_s kV (peak value)			**Rated lightning impulse withstand voltage** U_p kV (peak value)	
	Phase-to-earth and between phases (note 3)	**Across open switching device and/or isolating distance** (note 3)	**Phase-to-earth and across open switching device**	**Between phases** (notes 3 and 4)	**Across isolating distance** (notes 1, 2 and 3)	**Phase-to-earth and between phases**	**Across open switching device and/or isolating distance** (notes 2 and 3)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
300	460	595	850	1 275	700 (+245)	1 050	1 050 (+170)
362	520	675	950	1 425	800 (+295)	1 175	1 175 (+205)
420	650	815	1 050	1 575	900 (+345)	1 425	1 425 (+240)
550	710	925	1 175	1 760	900 (+450)	1 550	1 550 (+315)
800	960	1 270	1 425	2 420	1 100 (+650)	2 100	2 100 (+455)

NOTE 1 Column (6) is also applicable to some circuit-breakers, see IEC 62271-100.

NOTE 2 In column (6), values in brackets are the peak values of the power-frequency voltage $U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage).

In column (8), values in brackets are the peak values of the power-frequency voltage $0{,}7\ U_r \sqrt{2} / \sqrt{3}$ applied to the opposite terminal (combined voltage). See Annex D of IEC 60694.

NOTE 3 Values in column (2) are applicable:

a) for type tests, phase-to-earth and between phases;

b) for routine tests, phase-to-earth, phase-to-phase, and across the open switching device.

Values in columns (3), (4), (5), (6), (7) and (8) are applicable for type tests only.

NOTE 4 These values are derived using the multiplying factors stated in Table 3 of IEC 60071-1 (1993).

4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 60694 is applicable

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

Subclause 4.4.1 of IEC 60694 is applicable with the following addition

Some main circuits of GIS (e.g. busbars, feeder circuits, etc.) may have different values of rated normal current.

4.4.2 Temperature rise

Subclause 4.4.2 of IEC 60694 is applicable with the following addition

The temperature rise of components contained in the GIS which are subject to standards not covered by the scope of IEC 60694 shall not exceed the temperature-rise limits permitted in the relevant standard for those components.

NOTE When applying a temperature rise equal to or higher than 65 K for parts of the enclosure not accessible to the operator, every precaution is to be taken to ensure that no damage is caused to the surrounding insulating materials

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEC 60694 is applicable.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 60694 is applicable with the following addition

NOTE In principle, the rated short-time withstand current and the rated peak withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components

4.7 Rated duration of short-circuit (t_k)

Subclause 4.7 of IEC 60694 is applicable.

4.8 Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)

Subclause 4.8 of IEC 60694 is applicable.

4.9 Rated supply frequency of closing and opening devices and of auxiliary circuits

Subclause 4.9 of IEC 60694 is applicable with the following addition:

The rated supply frequency of operating devices and auxiliary circuits is the frequency at which the conditions of operation and temperature rise of these devices and circuits are determined.

4.10 Rated pressure of compressed gas supply for insulation and/or operation

Subclause 4.10 of IEC 60694 is not applicable.

5 Design and construction

GIS shall be designed so that normal service, inspection and maintenance operations, earthing of connected cables, locating of cable faults, voltage tests on connected cables or other apparatus and the elimination of dangerous electrostatic charges, can be carried out safely, including the checking of phase sequence after installation and extension.

The design of the equipment shall be such that the agreed permitted movement of foundations and mechanical or thermal effects do not impair the assigned performance of the equipment.

All components of the same rating and construction which may need to be replaced shall be interchangeable.

The various components contained within the enclosure are subject to their relevant standards except where modified by this standard.

5.1 Requirements for liquids in switchgear and controlgear

Subclause 5.1 of IEC 60694 is not applicable.

5.2 Requirements for gases in switchgear and controlgear

Subclause 5.2 of IEC 60694 is applicable with the following addition:

For GIS new SF_6 in accordance with IEC 60376 and used SF_6 in accordance with IEC 60480 can be used.

NOTE 1 For checking of sulphur hexafluoride in service, refer to IEC 60480.

NOTE 2 For handling of sulphur hexafluoride, refer to IEC 61634.

NOTE 3 Values for used SF_6 are under consideration in TC 10, WG 15, and will be included in the next revision of IEC 60480.

5.3 Earthing of switchgear and controlgear

Subclause 5.3 of IEC 60694 is applicable, with the additional subclauses.

5.3.101 Earthing of the main circuit

To ensure safety during maintenance work, all parts of the main circuit to which access is required or provided shall be capable of being earthed.

Earthing may be made by

a) earthing switches with a making capacity equal to the rated peak withstand current, if there is still a possibility that the circuit connected is live;

b) earthing switches without a making capacity or with a making capacity lower than the rated peak withstand current, if there is certainty that the circuit connected is not live.

Furthermore, it shall be possible, after opening the enclosure, to connect removable earthing devices for the duration of the work on a circuit element previously earthed via an earthing switch.

5.3.102 Earthing of the enclosure

The enclosures shall be connected to earth All metal parts which do not belong to a main or an auxiliary circuit shall be earthed For the interconnection of enclosures, frames, etc , fastening (e g bolting or welding) is acceptable for providing electrical continuity

The continuity of the earthing circuits shall be ensured taking into account the thermal and electrical stresses caused by the current they may have to carry.

If using single-phase enclosed switchgear, a looping circuit, i.e. an interconnection between the enclosures of the three phases, should be installed for the induced current. Each of these looping circuits should be linked as directly as possible to the general earthing grid by a conductor capable to carry the short-circuit current.

NOTE The looping circuits are intended to avoid induced currents in the enclosures from flowing in the earthing circuits and earthing grid. They are usually dimensioned for rated current and located at the end of each section.

5.4 Auxiliary and control equipment

Subclause 5.4 of IEC 60694 is applicable.

5.5 Dependent power operation

Subclause 5.5 of IEC 60694 is applicable.

5.6 Stored energy operation

Subclause 5.6 of IEC 60694 is applicable.

5.7 Independent manual operation

Subclause 5.7 of IEC 60694 is not applicable.

5.8 Operation of releases

Subclause 5.8 of IEC 60694 is applicable.

5.9 Low- and high-pressure interlocking and monitoring devices

Subclause 5.9 of IEC 60694 is applicable with the following addition

For GIS only gas density is of importance.

The gas density or temperature compensated gas pressure in each compartment shall be continuously monitored. The monitoring device shall provide at least two sets of alarm levels for pressure or density (alarm and minimum functional pressure or density).

NOTE 1 When the rated filling density differs between adjacent compartments, a third alarm indicating overdensity may be used.

NOTE 2 Tolerances of the monitoring device, as well as possible differences in temperature between the monitoring device and the volume of gas being monitored, should be considered.

Gas monitoring devices shall be capable of being checked with the high-voltage equipment in service.

NOTE 3 Checking of gas monitoring may initiate wrong alarms which may initiate or inhibit switching operations.

5.10 Nameplates

Subclause 5.10 of IEC 60694 is applicable with the following addition:

GIS and all its operating devices and main components shall be provided with nameplates, as agreed between manufacturer and user. The nameplates shall be durable and clearly legible.

The individual nameplates of the components can be simplified, provided common information for the GIS is stated on one nameplate.

The manufacturer shall give information about the total amount of SF_6 contained in the GIS installation.

5.11 Interlocking devices

Subclause 5.11 of IEC 60694 is applicable with the following addition:

The following provisions are mandatory for apparatus installed in main circuits which are used as isolating distance and earthing:

- apparatus installed in main circuits, which are used for ensuring isolating distances during maintenance work, shall be provided with locking facilities to prevent closing;
- earthing switches shall be provided with locking facilities to avoid opening.

Earthing switches having a short-circuit making capacity less than the rated peak withstand current of the circuit should be interlocked with the associated disconnectors.

Switches having a short-circuit making capacity less than the rated peak withstand current, or a breaking capacity less than the rated normal current, and disconnectors should be interlocked with the associated circuit-breaker to prevent opening or closing of the switch or disconnector unless the associated circuit-breaker is open. However, on-load bus-transfer switching operations at multiple busbar substations shall be possible.

5.12 Position indication

Subclause 5.12 of IEC 60694 is applicable with the following addition:

Subclause 5.104.3.1 of IEC 62271-102 is applicable.

5.13 Degrees of protection by enclosures

Subclause 5.13 of IEC 60694 is applicable.

5.14 Creepage distances

Subclause 5.14 of IEC 60694 does not apply to GIS.

5.15 Gas and vacuum tightness

Subclause 5.15 of IEC 60694 is applicable with the following addition:

Leakage losses and handling losses shall be considered separately.

NOTE 1 The objective is to achieve a total loss (leakage and handling) as low as possible. A value of less than 15 % averaged over all gas compartments and for the service period of minimum 25 years should be achieved.

NOTE 2 The cause of abnormal leakage in service should be investigated carefully and corrective actions should be considered.

5.15.1 Controlled pressure systems for gas

Subclause 5.15.1 of IEC 60694 is not applicable.

5.15.2 Closed pressure systems for gas

Subclause 5.15.2 of IEC 60694 is applicable.

5.15.3 Sealed pressure systems

Subclause 5.15.3 of IEC 60694 is applicable.

5.15.101 Leakage

GIS shall be a closed pressure system or a sealed pressure system.

If it is a closed pressure system, the leakage rate from any single compartment of GIS to atmosphere and between compartments shall not exceed 0,5 % per year for the service life of the equipment.

NOTE The procedure of Annex E of IEC 60694 may be used.

5.15.102 Gas handling

The GIS shall be designed so as to minimize gas-handling losses during service life. The manufacturer shall specify test and maintenance procedures for minimizing gas-handling losses and shall identify the gas loss associated with each procedure.

The manufacturer shall recommend procedures for SF_6 handling according to IEC 60480 and IEC 61634.

5.16 Liquid tightness

Subclause 5.16 of IEC 60694 is not applicable.

5.17 Flammability

Subclause 5.17 of IEC 60694 is applicable.

5.18 Electromagnetic compatibility (EMC)

Subclause 5.18 of IEC 60694 is applicable.

5.101 Pressure coordination

The pressure inside a GIS may vary from the rated filling pressure level due to different service conditions. Pressure increase due to temperature and leakage between compartments may impose additional mechanical stresses. Pressure decrease due to leakage may reduce the insulation properties. Figure 101 shows the various pressure levels and their relationship.

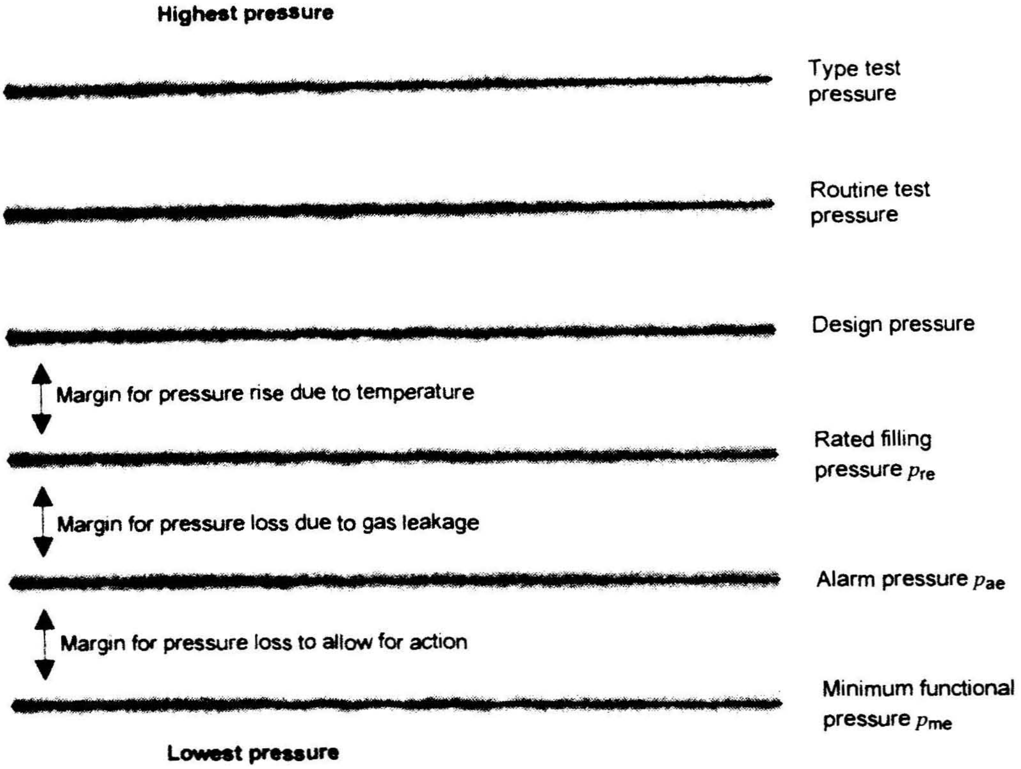
Highest pressure
Type test pressure
Routine test pressure
Design pressure
Margin for pressure rise due to temperature
Rated filling pressure p_{re}
Margin for pressure loss due to gas leakage
Alarm pressure p_{ae}
Margin for pressure loss to allow for action
Minimum functional pressure p_{me}
Lowest pressure

Figure 101 – Pressure coordination

The manufacturer is responsible for choosing the minimum functional pressure for insulation and operation p_{me}. The rated filling pressure p_{re} is related to the alarm pressure p_{ae} and the leakage rate in order to reach a sufficient period for refilling.

The time between the alarm pressure p_{ae} and the minimum functional pressure p_{me} should allow sufficient reaction time to permit actions. The tolerances of the gas monitor devices should be considered.

In service conditions, the mechanical stresses are associated with the internal pressure which depends on the gas temperature. Consequently, the design pressure corresponds to the rated filling pressure at the maximum temperature the gas can reach.

Routine test pressure and type test pressure are based on design pressure taking into account material and manufacturing process factors.

5.102 Internal fault

5.102.1 General

A fault leading to arcing within GIS built to this standard has a low order of probability. This results from the application of an insulating gas other than air at atmospheric pressure which will not be altered by pollution, humidity or vermin.

Arrangements should be made to minimize the effects of internal faults leading to arcing on the continued service capability of the switchgear. The effect of an arc should be confined to the compartment in which the arc has been initiated, or to the other compartments in the faulty section if pressure relief is used between compartments within this section. After disconnection of the compartment or section, restoration of the normal operation of the remaining equipment should be possible.

5.102.2 External effects of the arc

The effects of an internal arc are

- pressure increase of gas (see Clause D.1),
- possible burn-through of enclosure.

In order to provide a high protection to personnel, the external effects of the arc shall be limited (by a suitable protective system) to the appearance of a hole or a tear in the enclosure without any fragmentation.

The duration of the arc is related to the performance of the protective system determined by the first stage (main protection) and second stage (back-up protection).

Table 104 gives the performance criteria for the duration of the arc according to the performance of the protective system.

Table 104 – Performance criteria

Rated short-circuit current	Protection stage	Duration of current	Performance criteria
<40 kA r.m.s.	1	0.2 s	No external effect other than the operation of suitable pressure relief devices
	2	≤0.5 s	No fragmentation (burn-through is acceptable)
≥40 kA r.m.s.	1	0.1 s	No external effect other than the operation of suitable pressure relief devices
	2	≤0.3 s	No fragmentation (burn-through is acceptable)

Manufacturer and user may define a time during which an arc due to an internal fault up to a given value of short-circuit current will cause no external effects. The definition of this time shall be based on test results or an acknowledged calculation procedure. See Clause D.1.

The duration of current without burn-through for different values of the short-circuit current may be estimated from an acknowledged calculation procedure.

5.102.3 Internal fault location

The manufacturer of the GIS should propose appropriate methods for the determination of the location of a fault, if required by the user.

5.103 Enclosures

5.103.1 General

The enclosure shall be capable of withstanding the normal and transient pressures to which it is subjected in service.

5.103.2 Design of enclosures

The design of the enclosure shall be made in accordance with established standards for pressurized enclosures of gas-filled, high-voltage switchgear and controlgear with inert, non-corrosive, low pressurized gases. For further information, consult the bibliography.

Methods for the calculation of the thickness and the construction of enclosures either by welding or casting shall be based on the design pressure defined in 3.113.

NOTE When designing an enclosure, account should also be taken of the following:

a) the possible evacuation of the enclosure as part of the normal filling process;

b) the full differential pressure possible across the enclosure walls or partitions;

c) the resulting pressure in the event of an accidental leak between the compartments in the case of adjacent compartments having different service pressures if overpressure is not monitored;

d) the possibility of the occurrence of an internal fault (see 5.102).

In determining the design pressure, the gas temperature shall be taken as the mean of the upper limits of the enclosure temperature and the main circuit conductor temperature with rated normal current flowing unless the design pressure can be established from existing temperature-rise test records.

For enclosures and parts thereof, the strength of which has not been fully determined by calculation, proof tests (see 6.103) shall be performed to demonstrate that they fulfil the requirements.

Materials used in the construction of enclosures shall be of known and certified minimum physical properties on which calculations and/or proof tests are based. The manufacturer shall be responsible for the selection of the materials and the maintenance of these minimum properties, based on certification of the material supplier, or tests conducted by the manufacturer, or both.

5.104 Partitions

5.104.1 Design of partitions

Since, in service, most partitions have the same pressure on either side or small differential pressure, the significant pressure is that determined by the maintenance pressure. This will exist when the partition is pressurized on one side and maintenance is being carried out on the other side at atmospheric pressure. There are designs, however, where the partition is pressurized on one side and atmospheric pressure exists at all times on the other side. In both cases, the pressure to be considered on the pressurized side of the partition is the pressure at maximum ambient temperature with solar radiation effects (where applicable) and rated continuous current (where applicable). In both cases the pressure so derived is the design pressure of the partition. The manufacturer may, if he wishes, prescribe that the pressure on the pressurized side of the partition be lowered to a specified and controlled pressure during maintenance. In such cases this pressure is the design pressure.

When designing a partition, account shall be taken of the following if applicable

- the full differential pressure across the partition during normal operation
- evacuation of a gas compartment on one side of the partition with normal operating pressure on the other, as part of the filling process
- a controlled enhanced pressure on one side of the partition with normal operating pressure on the other during electrical testing of the equipment and associated circuits.
- for non-symmetrical partitions, as far as the pressure on the partition is concerned, the worst-case pressure direction,
- superimposed loads and vibration;
- the possibility of maintenance being carried out adjacent to a pressurized partition

5.104.2 Partitioning

GIS shall be divided into compartments in such a manner that both the normal operating conditions are met and a limitation of the effects of an arc inside the compartment is obtained (see 5.102.1).

For this purpose, partitions are required to ensure that the dielectric characteristics in one compartment are not substantially altered when an adjacent compartment is at reduced pressure due to leaks or maintenance operations. They are generally of insulating material but are not intended in themselves to provide electrical safety of personnel, for which other means such as separating by an isolating distance and earthing of the equipment may be necessary, they shall, however, provide mechanical safety against the normal gas pressure still present in the adjacent compartment.

It should be considered that the number of partitions, the size of the different gas compartments and the operational and maintenance strategies of the user might influence the handling losses of SF_6 as well as the outage time of the equipment.

A partition separating a compartment filled with insulating gas from a neighbouring compartment filled with liquid, such as a cable box or a voltage transformer, shall not show any leakage affecting the dielectric properties of the two media.

Figure 102 gives an example of an arrangement of enclosures and partitions for different types of adjacent compartments.

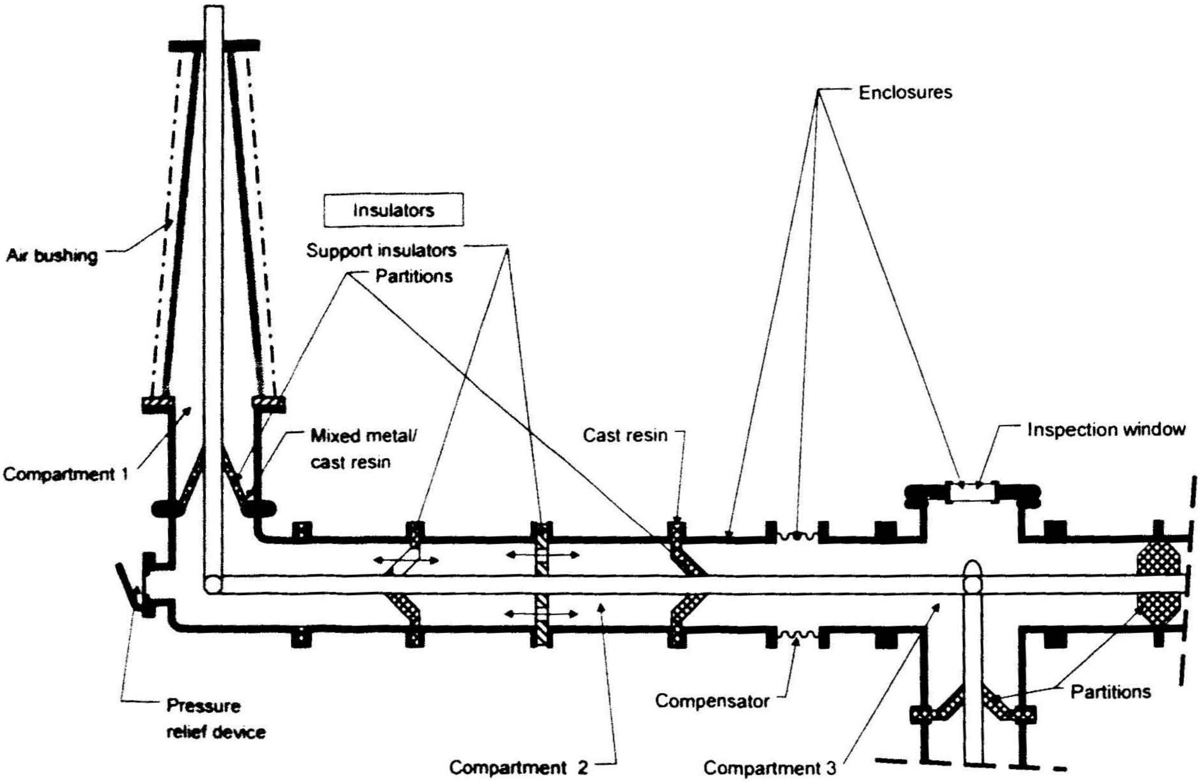

Figure 102 – Example of arrangement of enclosures and gas compartments

5.105 Pressure relief

Pressure relief devices in accordance with this subclause shall be arranged so as to minimize the danger to an operator during the time he is performing his normal operating duties in the gas-insulated substation if gases or vapours are escaping under pressure.

NOTE The term "pressure relief device" includes both pressure relief valves, characterized by an opening pressure and a closing pressure, and non-reclosing pressure relief devices, such as diaphragms and bursting disks.

5.105.1 Limitation of maximum filling pressure

For filling a gas compartment, a pressure relief valve shall be fitted to the filling pipe to prevent the gas pressure from rising to more than 10 % above the design pressure during the filling of the enclosure. Alternatively the valve may be fitted to the enclosure itself.

After an opening operation of a pressure relief valve, it shall reclose before the pressure has fallen to 75 % of the design pressure.

The filling pressure should be chosen to take into account the gas temperature at the time of filling.

5.105.2 Limitation of pressure rise in the case of an internal fault

Since, after an arc due to an internal fault the damaged enclosures will be replaced pressure relief devices need only be proportioned to limit the external effects of the arc (see 5 102 2)

Pressure relief devices protect against overpressure in case of internal failure For safety reasons and in order to limit consequences on GIS, it is recommended that each compartment be equipped with a pressure relief device except for large volumes where the overpressure is self-limited to values which do not exceed the type test pressure For the calculation method see Annex D.

The pressure relief device shall be equipped with a deflector in order to control the direction of emission in such a way that there is no danger for an operator working in accessible places for normal operation.

In order to avoid any pressure relief operation under normal conditions a sufficient difference is necessary between the operation pressure of the pressure relief device and the design pressure. Moreover, transient pressure occurring during operation (if applicable e g circuit-breaker) shall be taken into account when determining the operating pressure of the pressure relief device.

NOTE In the case of an internal fault which causes yielding of the enclosure enclosures of adjacent compartments should be checked for absence of distortion

5.106 Noise

During an operation, the level of noise emitted by the switchgear should not exceed a specified value. The procedure of verification should be agreed between manufacturer and user (see IEC 61672-1 and IEC 61672-2).

5.107 Interfaces

In order to facilitate testing of GIS, isolating facilities may be included in the design in each of the components mentioned below This type of separation is preferable rather than dismantling For air bushing, the high-voltage connection can be removed preferably on the air side

The isolating facilities shall be designed to withstand the test voltages of the components mentioned below.

5.107.1 Cable connections

Refer to IEC 60859.

Those parts of the GIS which remain connected to the cable shall be capable of withstanding the cable test voltages specified in the relevant cable standards for the same rated voltage for equipment (for oil-filled and gas-pressure cables see IEC 60141-1, for extruded cables see IEC 60840 and IEC 62067).

If it is not acceptable to apply DC cable test voltages to the GIS, special provisions for cable testing shall be made (e.g. disconnecting facilities and/or increasing of the gas density for insulation).

During dielectric tests on cables in general, the adjacent parts of the GIS should be de-energized and earthed, unless special measures are taken to prevent disruptive discharges in the cable affecting the energized parts of the GIS.

The location of suitable bushings for cable testing with DC and/or AC voltages should be provided at the cable connection enclosure or at the GIS itself (see IEC 60859).

5.107.2 Direct transformer connections

Refer to IEC 61639.

5.107.3 Bushings

Refer to IEC 60137 (outdoor-immersed bushing, definition 2.18), IEC 60815, IEC 62155 and IEC 61462.

5.107.4 Interfaces for future extensions

When an extension is planned, the locations of any possible future extension should be considered and stated by the user in the technical specification.

In the case of later extension with another GIS product and if requested by the user, the manufacturer shall supply information preferably in the form of drawings giving sufficient information to enable such an interface to be designed at a later stage. The procedure to ensure confidentiality of the design details shall be agreed between the user and manufacturer.

The interface should concern busbars or busducts only, and not direct connections to "active" devices such as circuit-breakers or disconnectors. If an extension is planned, it is recommended that the interface incorporates facilities for installation and testing of the extension to limit the part of the existing GIS to be re-tested and to allow the connection to the existing GIS without further dielectric testing (refer to Clause C.3). It shall be designed to withstand the rated insulation levels across the isolating distance.

The responsibility for testing the existing GIS is with the user.

5.108 Corrosion

Caution shall be taken against corrosion of the equipment during its service life. All bolted or screwed parts of the enclosure shall remain easily dismantled. In particular, galvanic corrosion between materials in contacts shall be considered because it can lead to loss of tightness. The continuity of the earthing circuits shall be ensured taking into account the corrosion of bolted and screwed assemblies.

6 Type tests

6.1 General

Subclause 6.1 of IEC 60694 is applicable with the following addition:

For type tests, new SF_6 in accordance with IEC 60376 or used SF_6 in accordance with IEC 60480 can be used. See 5.2.

6.1.1 Grouping of tests

Subclause 6.1.1 of IEC 60694 is applicable with the following addition:

As a general rule, tests on GIS components should be carried out in accordance with their relevant standards, unless a specific test specification or condition is defined in this standard. For such cases, the condition given in this standard shall be taken into account.

Unless specific testing prescriptions are defined, type testing shall be carried out on a complete functional unit (single-phase or three-phase). When this is impracticable, type tests can be made on representative assemblies or sub-assemblies.

Because of the variety of types, ratings and possible combinations of components, it is impracticable to subject all arrangements of the GIS to type tests. The performance of any particular arrangement may be substantiated from test results obtained on representative assemblies or sub-assemblies. The user shall check that tested sub-assemblies are representative of the users' arrangement.

The type tests and verifications are listed in Table 105 below. As proposed in IEC 60694, some tests can be grouped. An example of a possible grouping is also shown in Table 105.

Table 105 – Example of grouping of type tests

Mandatory type tests

Group		Subclause
1	a) Tests to verify the insulation level of the equipment and dielectric tests on auxiliary circuits	6 2
-	b) Tests to prove the radio interference voltage (RIV) level (if applicable)	6 3
2	c) Tests to prove the temperature rise of any part of the equipment and measurement of the resistance of the main circuit	6 4 and 6 5
3	d) Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short-time withstand current	6 6
3	e) Tests to verify the making and breaking capacity of the included switching devices	6 101
4	f) Tests to prove the satisfactory operation of the included switching devices	6 102 1
4	g) Tests to prove the strength of enclosures	6 103
4	h) Verification of the degree of protection of the enclosure	6 7
4	i) Gas tightness tests	6 8
5	j) Electromagnetic compatibility tests (EMC)	6 9
5	k) Additional tests on auxiliary and control circuits	6 10
4	l) Tests on partitions	6 104
4	m) Tests to prove the satisfactory operation at limit temperatures	6 102 2
-	n) Tests to prove performance under thermal cycling and gas tightness tests on insulators	6 106
-	o) Corrosion test on earthing connections (if applicable)	6 107

Type tests, when requested by the user (additional test samples may be used)

Group		Subclause
	p) Tests to assess the effects of arcing due to an internal fault	6.105

6.1.2 Information for identification of specimens

Subclause 6.1.2 of IEC 60694 is applicable.

6.1.3 Information to be included in type-tests reports

Subclause 6.1.3 of IEC 60694 is applicable.

6.2 Dielectric tests

Subclause 6.2 of IEC 60694 is applicable with the following addition:

Annex F of IEC 60694 is not applicable.

Dielectric tests performed as type tests shall be followed by a partial discharge measurement according to the test procedure described in 6.2.9.

6.2.1 Ambient air conditions during tests

Subclause 6.2.1 of IEC 60694 is applicable with the following addition:

No atmospheric correction factors should be applied for dielectric tests on GIS.

6.2.2 Wet test procedure

Subclause 6.2.2 of IEC 60694 is not applicable but the following points need to be noted:

- the wet test is applicable to outdoor bushings only;
- the test voltage and the test procedure shall be those specified in IEC 60137.

6.2.3 Conditions of switchgear and controlgear during dielectric tests

Subclause 6.2.3 of IEC 60694 is applicable.

6.2.4 Criteria to pass the test

Subclause 6.2.4 of IEC 60694 is applicable with the following addition:

b) Impulse tests

The test object has passed the impulse tests if the following conditions are fulfilled:

- the number of disruptive discharges shall not exceed two for each series of 15 impulses of each polarity.
- no disruptive discharge on non-self-restoring insulation shall occur.

This is verified by at least five impulses without disruptive discharge following the impulse out of the series of 15 impulses which caused the last disruptive discharge.

If this impulse is one of the last five out of the series of 15 impulses additional impulses shall be applied.

It is especially important for GIS to check the dielectric strength in order to eliminate all possible reasons for an internal fault in service. Therefore, if any disruptive discharges occur during the type test series, it is highly recommended to use all possible measures to find the location of flashover and to analyse the reason for it. It has to be stated in which way the reason for this insulation failure can be avoided during the manufacturing process.

6.2.5 Application of the test voltage and test conditions

Subclause 6.2.5 of IEC 60694 is applicable with the following addition.

The test voltages are specified in 6.2.6 and 6.2.7.

When each phase is individually enclosed in a metallic enclosure (single-phase design), only tests to earth, and no test between phases, are carried out. Bushings, used for external connections, shall be tested according to the relevant standards.

If an inspection window exists, a dielectric test is made with an earthed metal foil covering the accessible side of the inspection window.

Current transformers secondaries shall be short-circuited and earthed during impulse voltage testing.

Attention shall be given to the possibility that switching devices, in their open position, may result in less favourable field conditions. Under such conditions, the test shall be repeated in the open position. If, in the open position of a disconnector, an earthed metallic screen is interposed between the open contacts, this contact gap is not an isolating distance.

When voltage transformers and/or surge arresters forming an integral part of the GIS have a reduced insulation level, they may be replaced during the dielectric tests by replicas reproducing the field configuration of the high-voltage connections. Overvoltage protection devices shall be disconnected or removed during the tests. When this procedure is adopted, the voltage transformers and/or surge arresters shall be separately tested in accordance with the relevant standards.

Special requirements are prescribed in details in Annex A.

6.2.5.1 General case

Subclause 6.2.5.1 of IEC 60694 is applicable.

6.2.5.2 Special case

Subclause 6.2.5.2 of IEC 60694 is applicable with the following addition.

When the test voltage across the open switching device or across the isolating distance is higher than the phase-to-earth withstand level, but equal to the phase-to-phase withstand level, the test voltage shall be applied according to 6.2.5.2 of IEC 60694.

For switchgear and controlgear of $U_r \leq 245$ kV, the test across the isolating distance can be performed with the test voltage applied to one side of the isolating distance and the other side grounded or according to 6.2.5.2 of IEC 60694.

When the phase-to-phase withstand level is higher than the phase-to-earth withstand level, the test voltage shall be applied according to Annex A.

6.2.6 Tests of switchgear and controlgear of $U_r \leq 245$ kV

The rated withstand voltages shall be those specified in Table 102.

6.2.6.1 Power-frequency voltage tests

Subclause 6.2.6.1 of IEC 60694 is applicable with the following addition:

The main circuits of the GIS shall be subjected to power-frequency voltage tests in dry conditions only.

6.2.6.2 Lightning impulse voltage tests

Subclause 6.2.6.2 of IEC 60694 is applicable with the following addition:

If the alternative method described in 6.2.5.2 of IEC 60694 is used, the test voltage is defined in Column 5 of Table 102.

6.2.7 Tests of switchgear and controlgear of rated voltage for equipment above 245 kV

The rated withstand voltages shall be those specified in Table 103.

6.2.7.1 Power-frequency voltage tests

Subclause 6.2.7.1 of IEC 60694 is applicable.

6.2.7.2 Switching impulse voltage tests

Subclause 6.2.7.2 of IEC 60694 is applicable with the following addition:

The main circuits of the GIS shall be subjected to switching impulse voltage tests in dry conditions only

Special test requirements shall be used for the phase-to-phase switching test for a three-phase design. They are defined in detail in Annex A.

6.2.7.3 Lightning impulse voltage tests

Subclause 6.2.7.3 of IEC 60694 is applicable.

6.2.8 Artificial pollution tests

Subclause 6.2.8 of IEC 60694 is not applicable.

6.2.9 Partial discharge tests

Partial discharge tests shall be performed and the measurement made in accordance with IEC 60270

The measurement of partial discharges shall be performed after the dielectric type testing

The test may be carried out on assemblies or sub-assemblies of the equipment used for all dielectric type tests.

NOTE Power-frequency voltage tests and partial discharge tests can be performed at the same time

6.2.9.101 Test procedure

The applied power-frequency voltage is raised to a pre-stress value which is identical to the power-frequency withstand voltage test and maintained at that value for 1 min. Partial discharges occurring during this period shall be disregarded. Then, the voltage is decreased to a specific value defined in Table 106 depending on the configuration of equipment and system neutral for partial discharge measurement.

The extinction voltage shall be recorded.

Table 106 – Test voltage for measuring PD intensity

	System with solidly earthed neutral		**System without solidly earthed neutral**	
	Pre-stress voltage $U_{\text{pre-stress}}$ **(1 min)**	**Test voltage for PD measurement** $U_{\text{pd-test}}$ **(>1 min)**	**Pre-stress voltage** $U_{\text{pre-stress}}$ **(1 min)**	**Test voltage for PD measurement** $U_{\text{pd-test}}$ **(>1 min)**
Single-phase enclosures design (phase-to-earth voltage)	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test}} = 1{,}2\ U_r / \sqrt{3}$	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test}} = 1{,}2\ U_r$
Three-phase enclosures design	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test, ph-ea}} = 1{,}2\ U_r / \sqrt{3}$ $U_{\text{pd-test, ph-ph}} = 1{,}2\ U_r$	$U_{\text{pre-stress}} = U_d$	$U_{\text{pd-test, ph-ea}} = 1{,}2\ U_r$

U_r	rated voltage for equipment
U_d	power-frequency withstand test voltage as per Table 102 and 103
$U_{\text{pre-stress}}$	pre-stress voltage.
$U_{\text{pd-test}}$	test voltage for PD measurement
$U_{\text{pd-test, ph-ea}}$	test voltage for PD measurement, phase-to-earth
$U_{\text{pd-test, ph-ph}}$	test voltage for PD measurement, phase-to-phase

In addition, all components shall be tested in accordance with their relevant standards

6.2.9.102 Maximum permissible partial discharge intensity

The maximum permissible partial discharge level shall not exceed 5 pC of the test voltage specified in Table 106.

The values stated above applies to individual components as well as to the sub-assemblies in which they are contained. However, some equipment, such as voltage transformers isolated with liquid, immersed or solid, have an acceptable level of partial discharge in accordance with their relevant standard greater than 5 pC. Any sub-assembly containing components with a permitted partial discharge intensity greater than 5 pC shall be considered acceptable if the discharge level does not exceed 10 pC. Components for which higher levels are accepted shall be tested individually and are not integrated to the sub-assembly during test.

6.2.10 Dielectric tests on auxiliary and control circuits

Subclause 6.2.10 of IEC 60694 is applicable with the following addition:

Current transformer secondaries shall be short-circuited and disconnected from earth. Voltage transformer secondaries shall be disconnected.

6.2.11 Voltage test as condition check

Subclause 6.2.11 of IEC 60694 is applicable with the following addition:

In the case of three-phase enclosed designs, this test shall be performed across open switching devices, isolating distances, phase-to-earth and phase-to-phase. .

The test voltage shall be 80 % of the value in Tables 102 and 103, Columns 2 and 3.

NOTE National exceptions are required for Canada, France and Italy where it is required by law that the test voltage during condition check across the isolating distance of a disconnector be 100 % of the rated power frequency test voltage.

6.3 Radio interference voltage (r.i.v.) test

Subclause 6.3 of IEC 60694 is applicable with the following addition:

This test applies only to bushings.

6.4 Measurement of the resistance of circuits

6.4.1 Main circuit

Subclause 6.4.1 of IEC 60694 is applicable with the following addition:

The resistance measurement applies to all GIS components before and after the temperature-rise tests and short-circuit tests.

The current used for the measurement shall be equal or greater than 100 A DC to obtain sufficient accuracy of the measurement.

6.4.2 Auxiliary circuits

Subclause 6.4.2 of IEC 60694 is applicable.

6.5 Temperature-rise tests

6.5.1 Conditions of the switchgear and controlgear to be tested

Subclause 6.5.1 of IEC 60694 is applicable.

6.5.2 Arrangement of the equipment

Subclause 6.5.2 of IEC 60694 is applicable with the following addition:

Except in the case when each phase is enclosed individually in a metallic enclosure, the tests shall be made with the rated number of phases and the rated normal current flowing from one end of the busbars to the terminals provided for the connection of cables.

When a single-phase test is permitted and carried out, the current in the enclosure shall be the rated current.

When testing individual sub-assemblies, the neighbouring sub-assemblies should carry the currents which produce the power loss corresponding to the rated conditions. It is admissible to simulate equivalent conditions by means of heaters or heat insulation, if the test cannot be made under actual conditions.

6.5.3 Measurement of the temperature and temperature rise

Subclause 6.5.3 of IEC 60694 is applicable.

6.5.4 Ambient air temperature

Subclause 6.5.4 of IEC 60694 is applicable.

6.5.5 Temperature-rise test of the auxiliary and control equipment

Subclause 6.5.5 of IEC 60694 is applicable.

6.5.6 Interpretation of the temperature-rise tests

Subclause 6.5.6 of IEC 60694 is applicable with the following addition.

For outdoor application, the manufacturer shall demonstrate that the temperature rise of the equipment will not exceed the limit acceptable under the service condition chosen in Clause 2.

NOTE The effect of solar radiation should be taken into account.

6.6 Short-time withstand current and peak withstand current tests

Subclause 6.6 of IEC 60694 is applicable.

6.6.1 Arrangement of the switchgear and of the test circuit

Subclause 6.6.1 of IEC 60694 is not applicable.

GIS with three-phase enclosures shall be subject to three-phase testing. GIS with single-phase enclosures shall be tested using single-phase with the full return current in the enclosure.

The tests shall be made on a representative assembly which should include all types of connections of bolted, welded, plug-in or otherwise jointed sections to verify the integrity of GIS components are joined together. Assemblies shall be tested such that specimens of all components and sub-assemblies of the design are subjected to the test. Tests shall be made using configurations that provide the most severe conditions.

6.6.2 Test current and duration

Subclause 6.6.2 of IEC 60694 is applicable.

6.6.3 Behaviour of switchgear and controlgear during test

Subclause 6.6.3 of IEC 60694 is applicable.

6.6.4 Conditions of switchgear and controlgear after test

Subclause 6.6.4 of IEC 60694 is applicable.

6.6.101 Tests on the main circuits

After the tests, the resistance measurement shall not vary more than 20 % with respect to its pre-test resistance measurement. Neither shall any deformation or damage to components or conductors within the enclosure which may impair good operation have been sustained.

Short connections to voltage transformers shall be considered as part of the main circuit, except for parts included in the voltage transformer compartment.

6.6.102 Tests on earthing circuits

The manufacturer shall demonstrate by tests or calculations the capability of earthing circuits to withstand the rated short-time and peak withstand current of the earthing system.

When verification tests are required by the user, earthing circuits of GIS which are factory assembled and comprise earthing conductors, earthing connections and earthing devices shall be tested as installed in the GIS with all associated components which may influence the performance or modify the short-circuit current.

After the test, no deformation or damage to the components or conductors within the enclosure which may impair good operation of the main circuit shall have been sustained. Some deformation and degradation of the earthing conductor, earthing connections or earthing devices is permissible, but the continuity of the earthing circuit shall be preserved.

6.7 Verification of the protection

Subclause 6.7 of IEC 60694 is applicable.

6.7.1 Verification of the IP coding

Subclause 6.7.1 of IEC 60694 is applicable.

6.7.2 Mechanical impact test

Subclause 6.7.2 of IEC 60694 is applicable.

6.8 Gas tightness tests

Subclause 6.8 of IEC 60694 is applicable with the following addition:

The measurement of gas tightness shall be performed together with the tests of 6.102 and 6.106 with each type of compartment comprising characteristic sealings of GIS as a type test to show that the leakage rate complies with 5.15.101 and will not be changed by influences caused by the mechanical and limit temperature type tests.

6.8.1 Controlled pressure systems for gas

Subclause 6.8.1 of IEC 60694 is not applicable.

6.8.2 Closed pressure systems for gas

Subclause 6.8.2 of IEC 60694 is applicable.

6.8.3 Sealed pressure systems

Subclause 6.8.3 of IEC 60694 is applicable.

6.9 Electromagnetic compatibility tests (EMC)

Subclause 6.9 of IEC 60694 is applicable.

6.10 Additional tests on auxiliary and control circuits

Subclause 6.10 of IEC 60694 is applicable.

6.101 Verification of making and breaking capacities

Switching devices forming part of the main circuit of GIS shall be tested to verify their rated making and breaking capacities according to the relevant standards and under the proper conditions of installation and use, i.e. they shall be tested as normally installed in the GIS with all associated components, the arrangement of which may influence the performance, such as connections, supports, etc.

NOTE In determining which associated components are likely to influence the performance, special attention should be given to mechanical forces due to short-circuiting, to the possibility of disruptive discharges, etc. It is recognized that, in some cases, such influences may be quite negligible.

6.102 Mechanical and environmental tests

Switching devices of GIS shall be submitted to mechanical operation and environmental tests in accordance with their relevant standards, and shall be tested in a representative assembly of all associated components, which may influence the performance, including auxiliary devices. All equipment shall withstand the stresses caused by the operation of switching devices.

6.102.1 Mechanical operation test at ambient temperature

Before and after the mechanical operation tests, the measurement of gas tightness according to 6.8 shall be performed to show that the leakage rate is not changed by influences caused by the mechanical type tests.

In addition to Annex E of IEC 62271-102, all switching devices fitted with interlocks shall be submitted to 50 operating cycles in order to check the operation of the associated interlocks. Before each operation the interlocks shall be set in the position intended to prevent the operation of the switching devices and one attempt shall then be made to operate each switching device. During these tests only normal operating forces shall be employed and no adjustment shall be made to the switching devices or interlocks.

6.102.2 Low- and high-temperature test

Operation tests at minimum and maximum temperature shall be performed in accordance with their relevant standards with the following additions:

After the test cycles, the following shall be noted:

- the pressure of the gases contained in the enclosure;
- the gas leakage over a period of 24 h.

6.103 Proof tests for enclosures

Proof tests are made when the strength of the enclosure or parts thereof is not calculated. They are performed on individual enclosures before the internal parts are added with testing conditions based on the design pressure stresses.

Proof tests may be either a type test, pressure test or a non-destructive pressure test, as appropriate to the material employed. For further information, consult the bibliography.

6.103.1 Type test pressure test

In the case of a type test pressure test, the pressure rise should not be faster than 400 kPa/min.

The type test pressure test requirements should be at least as follows:

Cast aluminium and composite aluminium enclosures:

- type test pressure = [3,5 / 0,7] × design pressure

NOTE The value 0,7 has been included to cover the possible variability of production castings. It is permitted to increase this factor to 1,0 if it can be justified by special material tests.

Welded aluminium and welded steel enclosures:

- type test pressure = [$(2{,}3 / \nu) \times (\sigma_t / \sigma_a)$] × design pressure

where

ν is the welding coefficient (1 for ultrasonic or radiography inspection of 10 % of welded section and 0,75 for visual inspection);

σ_t is the permissible design stress at test temperature;

σ_a is the permissible design stress at design temperature.

These factors are based on the minimum certified properties of the material used.

Additional factors may be required taking into account the methods of construction.

Any enclosure remaining intact after these pressures have been reached shall not be used for normal operation.

6.103.2 Non-destructive pressure test

In the case of a non-destructive pressure test using a strain indication technique, the following procedure should be applied:

Before the test, strain gauges capable of indicating strains to 5×10^{-5} mm/mm shall be affixed to the surface of the enclosure. The number of gauges, their position and their direction shall be chosen so that principal strains and stresses can be determined at all points of importance to the integrity of the enclosure.

Hydrostatic pressure shall be applied gradually in steps of approximately 10 % until the standard test pressure for the expected design pressure (see 7.101) is reached or significant yielding of any part of the enclosure occurs.

When either of these points is reached, the pressure shall not be increased further.

Strain readings shall be taken during the increase of pressure and repeated during unloading

Indication of localized permanent set may be disregarded provided there is no evidence of general distortion of the enclosure.

Should the curve of the strain/pressure relationship show a non-linearity, the pressure may be re-applied not more than five times until the loading and unloading curves corresponding to two successive cycles substantially coincide. Should coincidence not be attained, the design pressure and the test pressure shall be taken from the pressure range corresponding to the linear portion of the curve obtained during the final unloading.

If the standard test pressure is reached within the linear portion of the strain/pressure relationship, the expected design pressure shall be considered to be confirmed

If the final test pressure or the pressure range corresponding to the linear portion of the strain/pressure relationship (see above) is less than the standard test pressure, the design pressure shall be calculated from the following equation:

$$p = \frac{1}{1{,}1\,k}\left(p_y \frac{\sigma_a}{\sigma_t}\right)$$

where

p is the design pressure;

p_y is the pressure at which significant yielding occurs or the pressure range corresponding to the linear portion of the strain/pressure relationship of the most highly strained part of the enclosure during final unloading (see above);

k is the standard test pressure factor (see 7.101);

σ_t is the permissible design stress at test temperature;

σ_a is the permissible design stress at design temperature

Alternative procedures for non-destructive pressure tests may be agreed

6.104 Pressure test on partitions

The purpose of this test is to demonstrate the safety margin of the partition submitted to pressure in service condition.

The insulators shall be installed as for the maintenance condition. The pressure shall rise at a rate of not more than 400 kPa/min until rupture occurs

The type test pressure shall be greater than three times the design pressure

6.105 Test under conditions of arcing due to an internal fault

Evidence of performance according to 5.103.2 shall be demonstrated by the manufacturer when required by the user. Evidence can consist of a test or calculations based on test results performed on a similar arrangement or a combination of both.

If such a test is required, the procedure shall be in accordance with the methods described in Annex B.

The short-circuit current applied during the arcing should correspond to the rated short-time withstand current or, in some applications of the switchgear in isolated neutral systems, it may be the earth fault current occurring in such a system.

Tests are not necessary in the case of single-phase GIS installed in isolated neutral or resonant earthed systems and equipped with a protection to limit the duration of internal earth faults

Two assessments are made. The first concerns the performance of the equipment during the operation of the first stage (main) protection and the second concerns the case when the fault is cleared by the operation of the second stage (back-up) protection.

In order to verify both assessments, the duration of the test shall be at least equal to the time delay of operation for the second stage of protection. The maximum time setting for the operation of the second stage is defined in Table 104. A shorter test duration can be used if it is not shorter than the operation of the second stage of protection defined by the user.

The switchgear should be considered adequate if the performance criteria defined in Table 104 are met.

6.106 Insulator tests

Tests on insulators (partitions and support insulators) shall be performed as follows:

6.106.1 Thermal performance

The thermal performance of each insulator design shall be verified by subjecting five insulators to ten thermal cycles each. Temperature values should be chosen according to Table 101.

The thermal cycle shall be as follows:

a) 4 h at minimum ambient air temperature (e.g. –40 °C);

b) 2 h at room temperature,

c) 4 h at limit of temperature according to Table 3 of IEC 60694 (e.g. +105 °C);

d) 2 h at room temperature.

The given thermal cycle times are minimum times and shall be prolonged in case stable end temperatures are not reached

After the test sequence, all insulators shall recover to the design characteristics. The minimum requirement is that the routine tests shall be withstood.

6.106.2 Tightness test for partitions

An overpressure withstand test shall be performed as described:

The design pressure shall be applied on one side of the partition while the adjacent compartment is under vacuum to verify the tightness of a partition. The leakage rate in the compartment under vacuum is measured over a period of 24 h.

At the end of the test, no damage shall be observed on the partition. A gas tightness test shall be performed in accordance with 6.8. The leakage rate shall not be greater than the defined value prescribed in 5.15

6.107 Corrosion test on earthing connections

For outdoor application, or on user's request, a corrosion proof test shall be performed in accordance with this subclause.

The user shall verify that the tested sub-assemblies are representative of the user's arrangement, including the devices providing electrical continuity and earthing of the enclosure the accessories (pressure monitoring device, pressure relief device) and the secondary system as described in 5.18 of IEC 60694.

6.107.1 Test procedure

The tested sub-assembly shall be submitted to environmental testing Ka (salt mist) according to IEC 60068-2-11. The duration of the test is 168 h.

In addition, for painted surfaces, the resistance to humid atmospheres containing sulphur dioxide shall be tested according to ISO 3231.

6.107.2 Criteria to pass the test

The resistance of the earthing of the enclosure measured according to 6.4.1 shall not differ by more than 20 % before and after this test.

After the test, the dismantling of the assemblies shall not be affected. The degree of corrosion, if any, should be indicated in the test report. If the surfaces are painted, no trace of degradation shall be noticed.

7 Routine tests

For routine tests new SF_6 in accordance with IEC 60376, or used SF_6 in accordance with IEC 60480, can be used. See 5.2.

The routine tests shall be performed on all components of a substation. Depending on the nature of tests, some tests may be performed on components, transport units or on the complete installation. The routine tests ensure that the product is in accordance with the equipment on which the type test has been carried out.

The following routine tests shall be carried out:	Subclause
a) Dielectric test on the main circuit	7.1
b) Tests on auxiliary and control circuits	7.2
c) Measurement of the resistance of the main circuit	7.3
d) Tightness test	7.4
e) Design and visual checks	7.5
f) Pressure tests of enclosures	7.101
g) Mechanical operation tests	7.102
h) Tests on auxiliary circuits, equipment and interlocks in the control mechanism	7.103
i) Pressure test on partitions	7.104

7.1 Dielectric test on the main circuit

7.1.1 Power-frequency voltage tests on the main circuit

Subclause 7.1 of IEC 60694 is applicable with the following addition:

The power-frequency voltage test of GIS shall be performed according to the requirements in 6.2.6.1 or 6.2.7.1 to earth, between phases (if applicable) and across the open switching devices. The voltage test across the open switching device may be carried out at one side of the switching device. The withstand voltages for routine tests shall be those specified in column 2 of Tables 102 and 103.

The tests shall be performed at the minimum functional pressure for insulation.

7.1.2 Partial discharge measurement

The measurement of partial discharges shall be performed to detect possible material and manufacturing defects.

Partial discharge tests shall be performed in accordance with 6.2.9.

The measurement of partial discharges shall be performed with dielectric tests after mechanical routine tests.

The test shall be carried out on all components of a substation. It may be performed on the complete installation, if applicable, or on transport units or on individual components. Tests on simple components containing no solid insulation may be excepted.

7.2 Tests on auxiliary and control circuits

Subclause 7.2 of IEC 60694 is applicable.

7.3 Measurement of the resistance of the main circuit

Subclause 7.3 of IEC 60694 is applicable with the following addition:

Overall measurements are made on sub-assemblies or, on transport units in the factory. Overall measurements shall be made in such a way that comparison with measurement taken on site after installation, during maintenance or repair of the installation is possible.

7.4 Tightness test

Subclause 7.4 of IEC 60694 is applicable with the following addition.

Leakage detection by using a sniffing device may be used. The sensitivity of the sniffing device shall be at least 10 ^{2} Pa cm^{3}/s. If a leak is detected with the leakage detector, then this leak shall be quantified by using a cumulative method as described in IEC 60694.

7.5 Design and visual checks

Subclause 7.5 of IEC 60694 is applicable.

7.101 Pressure tests of enclosures

Pressure tests shall be made on enclosures after complete machining.

The standard test pressure shall be k times the design pressure, where the factor k is

- 1.3 for welded aluminium and welded steel enclosures,
- 2 for cast aluminium and composite aluminium enclosures.

The test pressure shall be maintained for at least 1.0 min.

No rupture or permanent deformation should occur during this test.

7.102 Mechanical operation tests

Operation tests are made to ensure that the switching devices comply with the prescribed operating conditions and that the mechanical interlocks work properly.

Switching devices of GIS shall be submitted to a mechanical routine test in accordance with their relevant standards. The mechanical routine tests can be made before or after assembly of transport units.

In addition, all switching devices fitted with mechanical interlocks shall be submitted to five operating cycles in order to check the operation of the associated interlocks. Before each operation one attempt shall be made to operate each switching device as specified in 6.102.

During these tests, which are performed without voltage on or current in the main circuits, it shall be verified in particular that the switching devices open and close correctly within the specified limits of the supply voltage and pressure of their operating devices.

7.103 Tests on auxiliary circuits, equipment and interlocks in the control mechanism

All auxiliary equipment shall be tested either by a functional operation or by verification of the continuity of wiring. Settings relays or sensors shall be checked.

The electrical, pneumatic and other interlocks, together with control devices having a predetermined sequence of operations, shall be tested five times in succession in the intended conditions of use and operation and with the most unfavourable limit values of auxiliary supply. During the test no adjustment shall be made.

The tests are considered to be satisfactory if the auxiliary devices have operated properly, if they are in good operating condition after the tests and if the force to operate the switching device is practically the same before and after the tests.

7.104 Pressure test on partitions

Each partition shall be subjected to a pressure test at twice the design pressure for 1 min.

For the pressure test the partition shall be secured in exactly the same manner as in service.

The partition shall not show any sign of overstress or leakage.

8 Guide to the selection of switchgear and controlgear

See CIGRE 125, listed in the bibliography.

9 Information to be given with enquiries, tenders and orders

The intention of this clause is to define information which is necessary to enable the user to make an appropriate enquiry for a GIS and to enable the supplier to give an adequate tender.

Furthermore, it enables the user to make a comparison and evaluation of offers from different suppliers.

NOTE The supplier can either be a manufacturer or a contractor.

Annex E defines, in tabular format, technical information to be exchanged between user and supplier.

9.101 Information with enquiries and orders

In addition to the technical information given in Annex E, the following details should also be provided by the user:

a) the scope of supply should be defined for all equipment and services. This may include training, technical and layout studies and requirements for co-operation with the supplier;

b) special interlocking requirements;

c) indication should be given for every condition which might influence the tender or the order, e.g. special mounting or installation conditions, the locating of the external high-voltage connections or the rules for pressure vessels.

9.102 Information with tenders

In addition to the technical information given in Annex E, the following details should also be provided by the supplier:

a) constructional features:
   1) arrangement of the external connections including provisions for future extensions if requested;
   2) provisions for transport to be taken by the user;
   3) provisions for mounting to be taken by the user.

b) information concerning operation and maintenance;

c) in addition to the list of type test reports (see Clause E.4), the first pages of the reports containing the results may be requested. On special request, the manufacturer shall supply the complete type test reports.

10 Rules for transport, storage, installation, operation and maintenance

Clause 10 of IEC 60694 is applicable.

10.1 Conditions during transport, storage and installation

Subclause 10.1 of IEC 60694 is applicable.

10.2 Installation

Subclause 10.2 of IEC 60694 is applicable.

10.2.101 Tests after installation on site

After installation, and before being put into service, the GIS shall be tested in order to check the correct operation and the dielectric integrity of the equipment.

These tests and verifications comprise	Subclause
a) dielectric tests on the main circuits	10.2.101.1
b) dielectric tests on auxiliary circuits	10.2.101.2
c) measurement of the resistance of the main circuit	10.2.101.3
d) gas tightness tests	10.2.101.4
e) checks and verifications	10.2.101.5
f) gas quality verifications	10.2.101.6

To ensure minimum disturbance, and to reduce the risk of moisture and dust entering enclosures and thus preventing correct operation of the switchgear, no obligatory periodic inspections or pressure tests concerning the enclosures are specified or recommended when the gas-insulated substation is in service. Reference shall be made, in any case, to the manufacturer's instruction book.

The manufacturer and user should agree on a commissioning test plan for tests on site.

10.2.101.1 Dielectric tests on the main circuits

10.2.101.1.1 General

Since it is especially important for GIS, the dielectric integrity shall be checked in order to eliminate fortuitous causes (wrong fastening, damage during handling, transportation, storage and installation, presence of foreign bodies, etc.) which might in the future give rise to an internal fault.

Because of their different purpose, these tests shall not replace the type tests or the routine tests carried out on the transport units and, as far as possible, in the factory. They are supplementary to the dielectric routine tests with the aim of checking the dielectric integrity of the completed installation and of detecting irregularities as mentioned above. Normally the dielectric test shall be made after the GIS has been fully installed and gas-filled at the rated filling density preferably at the end of all site tests, when newly installed. Such a dielectric test is also recommended to be performed after major dismantling for maintenance or reconditioning of compartments. These tests shall be distinguished by their progressive voltage increase, performed in order to achieve some form of electrical conditioning of the equipment before commissioning.

The execution of such site tests is not always practicable and deviations from the standard tests may be accepted. The aim of these tests is to offer a final check before energizing. It is very important that the chosen test procedure does not jeopardize sound parts of the GIS.

In choosing an appropriate test method for each individual case, a special agreement may be necessary in the interest of practicability and economy, e.g. the electrical power requirements and the dimensions and weight of the test equipment may need to be considered.

A detailed test programme for the dielectric tests on site shall be agreed between manufacturer and user.

10.2.101.1.2 Test procedure

The GIS shall be installed completely and gas-filled at its rated filling density.

Some parts may be disconnected for the test, either because of their high charging current or because of their effect on voltage limitation, such as

- high voltage cables and overhead lines;
- power transformers and, occasionally, voltage transformers;
- surge arresters and protective spark gaps.

NOTE 1 In determining the parts which could be disconnected, attention is drawn to the fact that the reconnection may introduce faults after the tests are completed.

NOTE 2 Voltage transformers can remain connected for the test when saturation of the voltage transformer is prevented, e.g. by using voltage transformers which are designed for the test voltage or by performing the power frequency testing at a frequency, where saturation do not occur.

Every newly installed part of a GIS shall be subjected to a dielectric test on site.

In the case of extensions, in general, the adjacent existing part of the GIS should be de-energized and earthed during the dielectric test, unless special measures are taken to prevent disruptive discharges in the extension affecting the energized part of the existing GIS.

Application of the test voltage may be necessary after repair or maintenance of major parts or after installation of extensions. The test voltage may then have to be applied to existing parts in order to test all sections involved. In those cases, the same procedure should be followed as for newly installed GIS.

10.2.101.1.3 Dielectric test procedures

One of the following test procedures shall be chosen:

Procedure A (recommended for 170 kV and below)

Power-frequency voltage test for a duration of 1 min at the value specified in Table 107, Column 2.

Procedure B (recommended for 245 kV and above)

- Power-frequency voltage test for a duration of 1 min at the value specified in Table 107, Column 2; and
- partial discharge measurements according to Table 106, however with $U_{\text{pre-stress}} = U_{\text{ds}}$ of Table 107, Column 2.

A PD measurement at $U_r / \sqrt{3}$ is also recommended since this measurement may be helpful in determining the need for maintenance of the equipment after a period of service

For practical application of PD measurements, see Annex C

Procedure C (recommended for 245 kV and above, alternative to procedure B):

- Power-frequency voltage test for a duration of 1 min at the value specified in Table 107, Column 2; and
- lightning impulse tests with three impulses of each polarity and with the value specified in Table 107, Column 4.

10.2.101.1.4 Test voltages

Considering that

- transport units have normally been subjected to routine tests,
- the probability of disruptive discharges is higher for the complete installation than for individual functional units,
- disruptive discharges in correctly installed equipment shall be avoided

the test voltage for dielectric tests on site shall be as shown in Table 107

Table 107 – On site test voltages

Rated voltage for equipment U_r kV (r m s value)	On-site short-duration power-frequency withstand voltage U'_{ds} kV (r m s value)	On-site switching impulse withstand voltage U'_{ss} kV (peak value)	On-site lightning impulse withstand voltage U'_{ps} kV (peak value)
(1)	(2) (see Note 1)	(3)	(4)
72 5	120	-	260
100	165	-	360
123	200	-	440
145	235	-	520
170	270	-	600
245	380	680	840
300	380	680	840
362	425	760	940
420	515	840	1 140
550	560	940	1 240
800	760	1140	1 680

NOTE 1 Values of column (2) are only applicable for SF_6 insulation or when SF_6 is a major part of the gas mixture For other insulation refer to Tables 1 and 2 of IEC 60694, applying a factor 0,8 on column (2).

NOTE 2 The on-site test voltages have been calculated as follows:

U'_{ds} (on-site test value) = $U'_p \times 0,45 \times 0,8$ (column 2)

U'_{ss} (on-site test value) = $U'_s \times 0,8$ (column 3)

U'_{ps} (on-site test value) = $U'_p \times 0,8$ (column 4)

All values have been rounded up to the next higher modus 5 kV.

NOTE 3 If other insulation levels than the preferred values of Tables 102 and 103 (e.g. the lower insulation levels of Tables 1 and 2 in IEC 60694) are specified, then the on-site test voltage should be calculated according to Note 2

In certain circumstances, for technical or practical reasons, dielectric tests on site may be carried out with reduced voltage values. Details are given in Clause C.3.

10.2.101.1.5 Voltage waveforms

For the choice of an appropriate voltage waveform, IEC 60060-1 should be taken into consideration; however, similar waveforms are also permissible. An ideal voltage waveform covering all requirements does not exist. Permissible deviations are indicated below. Information concerning the generation of test voltages is given in Clause C.1.

1) **Power-frequency voltage tests**

   Power-frequency voltage tests are especially sensitive in detecting contaminations (e.g. free moving conducting particles), and are, in most cases, also sufficient in detecting abnormal field configurations.

   The existing experience refers to test frequencies from 10 Hz to 300 Hz.

2) **Impulse voltage tests**

   a) Tests with lightning impulse voltages are especially sensitive in detecting abnormal field configurations (e.g. damaged electrodes).

      Based on the existing experience, lightning impulse voltages with a front time extended up to 8 µs are acceptable. When using oscillating lightning impulse voltages, the front time may be extended to approximately 15 µs.

      NOTE Reflections due to steep front waves in large installations should be taken into account

   b) Tests with switching impulse voltages can be used especially for higher U_r, to detect the presence of contaminations as well as abnormal field configurations with relatively simple test equipment.

      Based on existing experience, switching impulses with either aperiodic or oscillating waveforms and with a time to crest in the range of 150 µs to 10 ms are suitable

3) **DC voltage tests**

   A DC voltage test cannot be recommended. The existing test specifications for cables are not applicable to GIS (refer to 5.107.1).

10.2.101.1.6 Voltage application

The test voltage source may be connected to any convenient point of the phase conductor under test.

It is often convenient to divide the whole installation of GIS into sections by opening circuit-breakers and/or disconnectors for at least one of the following reasons

- to limit the capacitive load on the test voltage source;
- to facilitate the location of disruptive discharges;
- to limit the discharged energy if a disruptive discharge occurs.

The sections which, in such cases, are not being tested, and which are isolated by a circuit-breaker or a disconnector from the section under test, shall be earthed. Unless dismantled after routine test, no dielectric test across the open switching devices need be carried out on site.

For 3-phase enclosed GIS, the specified test voltage shall be applied between each phase conductor, one at a time, and the enclosure, the other phase conductors being connected to the earthed enclosure. The insulation between phase conductors shall not be subjected to any other separate dielectric test on site.

10.2.101.1.7 Assessment of the test

The switchgear shall be considered to have passed the test if each section has withstood the specified test voltage without any disruptive discharge.

In the event of a disruptive discharge occurring during dielectric tests on site, the tests shall be repeated.

Guidelines on repetition tests are given in Clause C.6.

If Procedure B is used and if the partial discharges are measured with the conventional method according to IEC 60270, the maximum permissible intensity of partial discharge is 10 pC.

NOTE 1 It can be difficult to have noise level below 5 pC on-site. Special care with the test circuit is needed to achieve a good measurement. If the noise level is higher than 5 pC, the test is still valid for detecting major defects but not suitable for detection of fixed conducting particles since this kind of defect will cause a very low level of partial discharges and they will be completely masked by the noise. In such circumstances, the test is acceptable if no discharges are detected above the noise level.

NOTE 2 If VHF/UHF or acoustic partial discharge measuring methods are used, a calibration is not possible. Instead, a sensitivity check according to C.7.5 can be performed.

10.2.101.2 Dielectric tests on auxiliary circuits

Subclause 7.2 of IEC 60694 is applicable with the following addition:

Dielectric tests should be carried out on new wiring. If wiring has to be taken off or if electronic devices are in circuits, these circuits shall not be tested.

10.2.101.3 Measurement of the resistance of the main circuit

Overall measurements shall be made on the complete installation, under conditions as similar as possible to those of the routine test on transport units.

The resistance measured shall not exceed the maximum values permitted for the routine tests on transport units (see 7.3), taking into account the differences of the two test arrangements (number of devices, contacts and connections, length of conductors, etc.).

10.2.101.4 Gas tightness tests

Subclause 7.4 of IEC 60694 is also applicable for on-site gas tightness tests.

A qualitative gas tightness test shall be carried out on all field assembled connections. A leakage detector may be used.

10.2.101.5 Checks and verifications

The following shall be verified:

a) conformity of the assembly with the manufacturer's drawings and instructions;
b) sealing of all pipe junctions, and the tightness of bolts and connections;
c) conformity of the wiring with the diagrams;
d) proper function of the electrical, pneumatic and other interlocks;
e) proper function of the control, measuring, protective and regulating equipment including heating and lighting.

The mechanical operation checks and tests shall be carried out according to the relevant standards. If verification is not specified, the manufacturer shall specify them in the commissioning test plan.

10.2.101.6 Gas quality verifications

In order to get a reliable measurement, the moisture content shall be checked at least 5 days after final filling of gas. For SF_6 the moisture content shall not exceed the limit defined in 5 2 of IEC 60694.

For checking the condition of the gas during service, reference is made to IEC 60480

For handling precautions, reference is made to IEC 61634.

NOTE Care should be taken to minimize the release of gas into the atmosphere during sampling and/or checking operations (e.g. by providing a collecting bag or receiver installed on the outlet valve of the checking device when determining moisture content).

10.3 Operation

Subclause 10.3 of IEC 60694 is applicable.

10.4 Maintenance

Subclause 10.4 of IEC 60694 is applicable.

11 Safety

Clause 11 of IEC 60694 is applicable.

12 Environmental aspects

The manufacturer shall specify information regarding the relation between operation during service life of the equipment and environmental aspects. Subclause 10 4 1 a), item 2) of IEC 60694 is applicable.

The manufacturer shall give instructions concerning disassembly and end-of-life procedures for the different components of the equipment (composition, weight, toxicity, etc). Subclause 10.4.1 a), item10) of IEC 60694 is applicable.

Annex A
(normative)

Test procedure for dielectric test on three-phase encapsulated GIS, range II

A.1 Dielectric procedures for three phases in one GIS enclosure

If the requirements for phase-to-earth and phase-to-phase insulation levels are different, the test requirements following IEC 60694 have to be reconsidered. This is applicable only for switching impulse tests of range II.

A.2 Application of test requirements

In order to fully cover the tests to be carried out, Table A.101 lists the test conditions in relation to the enclosure, open switching device and phase-to-phase. The table symbols are the same as in IEC 60694 (Figure 2).

The preferred method is the use of combined voltage test. The voltage levels required may be delivered by two sources in phase opposition connected to the same voltage controller.

Table A.101 – Switching impulse test conditions above 245 kV

Test condition	**Connecting device**	**Switching impulse**	**Alternating voltage at power-frequency**	**Earth connected to**
Phase-to-phase test		**Main part of U_s between phases (Table 103, Column 5) applied to**	**Complementary part to obtain U_s between phases (Table 103, Column 5) applied to**	
1	Closed	Aa	BbCc	F
2	Closed	Bb	AaCc	F
3	Closed	Cc	AaBb	F
4	Open	A	BC	abcF
5	Open	B	AC	abcF
6	Open	C	AB	abcF
7	Open	a	bc	ABCF
8	Open	b	ac	ABCF
9	Open	c	ab	ABCF

NOTE Test conditions 3, 6 and 9 may be omitted if the arrangement of the outer phases is symmetrical with respect to centre phase and the enclosure.

For switching functions and disconnecting functions, respective values have to be taken in Table 103 for open conditions.

Annex B
(normative)

Methods for testing gas-insulated metal-enclosed switchgear under conditions of arcing due to an internal fault

B.1 Introduction

The occurrence of an arc inside GIS due to an internal fault is accompanied by various physical phenomena.

For example, the energy resulting from an arc developing in the enclosure will cause internal overpressure and local overheating, which will result in mechanical and thermal stressing of the switchgear. Moreover, the materials involved may produce hot decomposition products which may be discharged into the atmosphere.

This annex takes into account the internal overpressure acting on the enclosure and the thermal effects of the arc or its root on the enclosure. It does not cover all the effects which may constitute a risk, such as toxic gases.

B.2 Short-circuit current arcing test

B.2.1 Test arrangements

When choosing the object to be tested, reference shall be made to the design documents for the GIS. The compartments which appear to have the least likelihood of withstanding the pressure and temperature rise in the event of arcing shall be selected.

In any case, the following points shall be observed:

a) each test may be carried out on a test object not previously subjected to arcing tests. Test objects that have already undergone arcing tests shall be restored so that the conditions for further arcing tests are neither aggravated nor eased;

b) the test object shall be fully equipped and arranged to include any protection device, such as pressure reliefs, short-circuiting devices, etc. provided by the manufacturer for the limitation of the effects of the arc.

   "Mock-ups" are permitted provided they have the same volume and external material and would react in the same way as the original parts with respect to withstanding arcing.

c) the test object shall be filled with normal insulating gas at rated filling density.

B.2.2 Current and voltage applied

Single-phase enclosures shall be tested single-phase, and three-phase enclosures shall be tested three-phase.

B.2.2.1 Voltage

The test can be made with an applied voltage lower than the rated voltage for equipment of the test object if the following conditions are met:

a) the arc current shall be practically sinusoidal;

b) the arc shall not extinguish prematurely.

B.2.2.2 Current

a) **AC component**

The AC component at the beginning of the test shall lie within a $^{+10}_{\ 0}$ % tolerance. Within the duration of the first stage protection, the tolerance shall be ±10 % and within the duration of the second stage protection the current shall not fall below 80 % of the specified value, provided that the average AC component is not less than the stated short-circuit current.

NOTE If the test plant does not permit this, the test duration may be extended by not more than 20 % with an appropriate adjustment to the times at which assessments are made.

b) **DC component**

The instant of short-circuit making shall be chosen to ensure that the first loop of the arc-current has a peak value of at least 1,7 times the r.m.s. value of the stated short-circuit current AC component. For three-phase tests, this applies to the current in at least one phase.

B.2.2.3 Frequency

For rated frequencies of 50 Hz or 60 Hz, the frequency at the beginning of the test shall lie within the limits of 48 Hz and 62 Hz.

For 16 2/3 Hz or 25 Hz rated frequency, it is permissible to make tests with 25 Hz with a tolerance of ±10 %. The frequency at the beginning of the test may also lie within the limits of 48 Hz and 62 Hz, if the test duration is at least 0,1 s.

B.2.2.4 Duration of the test

The current duration shall be such as to cover the second stage protection chosen on the basis of the expected duration as determined by the protection devices. See Table 104.

B.2.3 Test procedure

B.2.3.1 Test connections

The point of current infeed to be chosen is the one likely to result in the most onerous condition.

Care shall be taken to ensure that the connections do not ease the test conditions. Generally, the enclosure is earthed on the same side of the test object into which the current is fed.

B.2.3.2 Arc initiation

The arc shall be initiated by means of a metal wire of suitable diameter.

The point of initiation to be chosen is where the arc is likely to set up the rated stresses in the test object. Generally, this will be achieved when the arc is initiated in the vicinity of a partition furthest from the point of infeed and furthest from the pressure relief device, if fitted.

NOTE The arc should not be initiated by perforating the solid insulation.

B.2.3.3 Measurement and recording of the test performance

The following parameters shall be plotted and recorded:

- the current and its duration;
- the arc voltage;
- the pressure on one or more points of the test object and in each compartment, if the test object comprises more than one;

and, when applicable

- the instant of pressure relief (either by operation of the pressure relief device or perforation of the enclosure).

Phenomena such as pressure relief, enclosure perforation and external effects shall be observed and recorded by appropriate means, e.g. cameras, luminosity detectors.

B.2.4 Assessment of the test

The switchgear is considered adequate if, during the test, no external effect other than the operation of suitable pressure relief devices occurs within the times specified in 5.102.2 and if gases or vapours escaping under pressure are directed so as to minimize the danger to an operator performing his normal operating duties.

No fragmentation of the enclosure shall result from a fault cleared within the stage 2 protection according to Table 104.

B.2.5 Test report

The following information shall be given in the test report:

- rating and description of the test object, the materials of the enclosure and the conductors, together with a drawing showing the main dimensions and the arrangement of pressure relief devices;
- arrangement of the test connections, the point of initiation of the arc and the position of the transducers for pressure measurements;
- currents, voltages, energies, pressures and times derived from the oscillograms;
- precise description of the test results and observations;
- other relevant remarks;
- photographs of the conditions before and after the test.

B.2.6 Extension of the test results

To extend the test results to other enclosures of similar design but of different size and shape and/or to other test parameters, calculation methods may be agreed between the manufacturer and user.

B.3 Composite verification by calculation and separate tests

The manufacturer is responsible for demonstrating the validity of extrapolation of test results for other currents and other sizes of enclosures. The manufacturer shall provide all necessary information with the calculation.

Annex C
(informative)

Technical and practical considerations of site testing

C.1 Test voltage generators

Load capacitances of GIS installations are relatively high. This means that

- power frequency voltage tests, especially at higher U_r, require a high reactive power,
- impulse testing with standardized double exponential waveforms may be inefficient due to the poor voltage utilization of the impulse generator.

The following voltage-generating equipment may be used:

a) **power frequency voltage sources**

The power frequency voltage may be produced by

- test sets with a test transformer,
- test sets with a variable resonant reactor for constant frequency,
- test sets with a constant resonant reactor for variable frequency,
- energizing power or voltage transformers from the low-voltage side which entails no dismantling after testing.

NOTE The thermal stresses of the voltage source should be taken into account especially when using voltage transformers.

b) **impulse voltage sources**

For large installations and especially for high voltages for equipment, impulse generators for double exponential waves are unwieldy. Oscillating impulses may be produced with an impulse generator and a high-voltage coil connected to the switchgear to be tested to form a damped series resonant circuit. Oscillating switching impulses may be produced by discharging a capacitor into the low-voltage side of a power, voltage or test transformer.

C.2 Locating discharges

There are different phenomena caused by discharges which may be helpful in locating them. Some of the possible means which may be tried are as follows:

- detection of light emission;
- measurement of audible noise and vibrations,
- recording and evaluation of electromagnetic transients following discharge;
- detection of decomposition products of the gas.

C.3 Special test procedures

In general, it is recommended that all testing should be performed at the specified test voltage and rated filling density. However, in certain circumstances special test procedures have been established which are not in general use but are worth mentioning for technical and/or practical reasons.

For extensions (5.107.4) the user shall be responsible for any flashovers in the existing GIS and the manufacturer of the extension equipment shall be responsible for any flashovers in the extension equipment.

C.3.1 Testing at reduced voltage

C.3.1.1 Simplified method for units transported without dismantling

In accordance with the practice in some countries, gas-insulated metal-enclosed switchgear, or at least one bay or an equivalent part of the GIS installation, may be assembled completely at the factory and tested there at its full rated withstand voltages. If the tested units are transported without dismantling or if dismantling is limited to very simple connections, and subject to agreement between manufacturer and user, the site test may be reduced to the following

AC voltage test with 1,1 × $U_r / \sqrt{3}$ for earthed neutral systems or 1,9 × $U_r / \sqrt{3}$ for isolated neutral or resonant earthed systems; with a 10 min voltage application.

C.3.1.2 Deviations due to practical needs

In certain circumstances due to technical or practical reasons, an AC voltage test may be performed at reduced voltage and for an extended duration, subject to agreement between the manufacturer and user.

C.3.1.3 Application of service voltage

In some cases, it is impracticable to perform a dielectric test on site. In such a case, special care should be taken for shipment, transportation and storage and particular attention should be given to the workmanship on site. The GIS to be tested should be energized by the service voltage through the largest possible impedance in order to reduce damage caused by a possible disruptive discharge. The test period should be at least 30 min.

C.3.2 Testing at reduced gas density

Tests with reduced gas density are not generally advisable.

C.4 Partial discharge measurements

Partial discharge measurements may be helpful in detecting certain kinds of faults during site tests and in determining the need for maintenance of the equipment after a period in service. They are therefore a useful complement to dielectric tests on site but are often difficult to perform because of ambient disturbances.

If such a test is possible and agreed upon, then the requirements given in 10.2.101.1.5 should be applied as far as possible.

C.5 Electrical conditioning

The term "electrical conditioning" means a progressive application of an AC voltage either by steps or continuously. It may be performed by the manufacturer as part of the gas-filling process on site in order to move possible particles towards areas with a low field strength where they become harmless.

Electrical conditioning is not a requirement and does not replace the AC voltage test, unless the test voltage is increased up to the specified value. Nevertheless, a disruptive discharge should be reported to the user as it may result in a weakening of the insulation.

C.6 Repetition tests

C.6.1 General

The procedure to be implemented following a disruptive discharge during dielectric tests on site may depend on several factors which include:

- the type of disruptive discharge (breakdown in self-restoring or non-self-restoring insulation) if it can be identified (see Clause C.2);
- magnitude of the arc energy dissipated during the discharge;
- shape and material of the solid insulation;
- strategic importance of the installation.

Consideration of these and any other relevant factors should allow a procedure to be established and agreed between the manufacturer and user. A recommended procedure is given below but should be treated only as a guide. Variations may be acceptable, depending on the significance of the factors involved.

C.6.2 Recommended procedure

C.6.2.1 Procedure a)

If the disruptive discharge occurs along the surface of a solid insulation it is recommended that wherever practicable the compartment should be opened and the insulation carefully inspected for impairments. After taking any necessary remedial action, the compartment should then be subjected to the specified dielectric test once more.

C.6.2.2 Procedure b)

A disruptive discharge in the gas may be due to contamination or a surface imperfection which may be burned away during the discharge. It may be acceptable, therefore, that the test may be repeated at the specified test voltage. Another test voltage may be agreed between manufacturer and user before the site tests have been started.

NOTE 1 It is assumed that the manufacturer can satisfy the user that the gaseous insulation may be regarded as self-restoring for the arc energy dissipated in the discharge.

NOTE 2 In the event of a disruptive discharge occurring during dielectric tests on site, secondary discharges can occur in other parts of the test section.

If the repetition test fails, again Procedure a) should be followed.

C.7 Partial discharge detection method

C.7.1 Introduction

For partial discharge detection on-site, the electrical VHF/UHF and the acoustic method can be used in GIS in addition to the conventional method, according to IEC 60270. These two methods are less sensitive to noise than the conventional measurement and can also be used for partial discharge monitoring in service. However, for these new methods the sensitivity depends on the distance between the defect (signal source) and the sensor. Suitable procedures for using the VHF/UHF and acoustic method are available. They ensure that defects causing an apparent charge of around a few pC can be found by such equipment. The proposed sensitivity verification can be easily performed on-site. The advantage of the two additional methods is that the location of the defects can be detected. The methods and the interpretation of the results can only be used by experienced personnel. The methods are still under investigation and are not yet standardized.

C.7.2 Conventional method according to IEC 60270

Electromagnetic interference from radio transmitters and other sources is picked up by open-air bushings and lead to a PD measurement sensitivity of some 10 pC. For noise rejection, analogue and digital filtering methods are available. Nevertheless, the use of such filtering tools requires trained personnel and is a limitation in this procedure. In actual site conditions, a noise level below 5 pC is hard to achieve. Therefore a totally encapsulated test circuit with a shielded coupling capacitor directly connected to the GIS is preferable. In such a case, a sensitivity below 5 pC is achievable for GIS with cable terminations and for GIS sections which are separated by an open disconnector from open-air bushings.

C.7.3 VHF/UHF method

The discharge currents at the defects of GIS have rise times that can be less than 100 ps. These defects cause electromagnetic transients with frequency content to above 2 GHz. The resulting signals propagate within a GIS with the speed of light as TEM-, TE- and TM-waves. Reflections occur at the numerous discontinuities in the arrangement. Due to the finite conductivity of the metallic conductors and losses at the dielectric surfaces, the propagating signals are damped. The result is a complex resonance pattern of electromagnetic waves within each compartment.

The partial discharge signals in the VHF/UHF range (e.g. 100 MHz – 2 GHz) can be detected in the time domain or the frequency domain by means of couplers, which are usually of similar design to capacitive couplers. As consequence of VHF/UHF signal attenuation, many couplers have to be installed in a GIS. The maximum distance between two adjacent couplers is approximately some tens of metres. The VHF/UHF signal is best taken from internal couplers, but when these are not available it is sometimes possible to use external couplers on windows or spacers.

Due to the complexity of the resonance patterns, the magnitude of the detected PD signal depends strongly on the location and, to a minor degree, on the orientation of the defect and the coupler. The VHF/UHF method can therefore not be calibrated as in, for example, the measuring circuit of IEC 60270. Instead, the sensitivity check in C.7.5 can be performed.

The signal-to-noise-ratio and therefore the sensitivity of the VHF/UHF measuring device can be improved by using suitable couplers, amplifiers and filters The VHF/UHF method has proved to be at least as sensitive in detecting defects as the conventional method and this is mainly due to the low external noise level. Tests in laboratories and on-site have shown that small critical defects and even non-critical defects may be detected

An accurate location of the defect may be obtained by using a broadband oscilloscope to measure the time interval between the signals arriving at adjacent couplers

C.7.4 Acoustic method

Acoustic signals (mechanical waves) are emitted from defects in a GIS mainly in two primary mechanisms: moving particles excite a mechanical wave in the enclosure when they impinge on it, whereas discharges from fixed defects create a pressure wave in the gas which is then transferred to the enclosure. The resulting signal will depend on the source and on the propagating path. As the enclosures normally are made of aluminium or steel the damping of the signals is quite small. However there is a loss of energy when the signals are transmitted from one part to another across a flange. Acoustic signals can be picked up by means of externally mounted sensors. Normally, either accelerometers or acoustic emission sensors are used and the test procedure consists of measuring between all flanges

The location of a defect can be found by searching for the acoustic signal with the highest amplitude or by time travel measurements with two sensors Separation between different kinds of defects is possible by analysing the shape of the acoustic signal

The signal from a bouncing particle is broadband (i e >1 MHz) and has a high amplitude compared with signals emitted from pre-discharges at fixed defects The particle type signal will be spatially attenuated as it moves away from the source point In general two parameters of the acoustic signal are important for this type of defect amplitude and flight time (this being the time between two consecutive impacts of the particle These parameters are essential not only for recognition of defect type but also for risk assessment

Predischarge type signals from protrusions will be very wideband close to the source but because the gas acts as a low pass filter, the high frequencies are attenuated as the signal propagates away from the source towards the enclosure Normally detected signals from predischarge sources are limited to the frequency range below 100 kHz The signal level is found to be fairly constant within the same sections and to drop some 8 dB once a flange is crossed.

Bouncing particles producing apparent discharges in the 5 pC range can be detected with a high signal-to-noise ratio The detection limit for corona discharges is in the 2 pC range Sensitivity decreases with distance because the acoustic signals are absorbed and attenuated as they propagate in the GIS However, no direct correspondence between apparent PD-level and acoustic signal level has been established Acoustic measurement is immune to electromagnetic noise in the substation The acoustic sensitivity to bouncing particles is usually much higher than the sensitivity of any other diagnostic method, when the sensor is placed close to the defect The acoustic method is therefore good for detecting the location of such defects.

C.7.5 Sensitivity verification of acoustic and UHF method

For the acoustic and the UHF method, the same technical principle is applied for the sensitivity verification of partial discharge detection. First, an artificial acoustic or electrical pulse is determined which emits a signal similar to that from a real defect that causes a defined level of apparent charge (e.g. 5 pC or more) according to IEC 60270. Secondly, this artificial pulse is injected during the commissioning test or operating conditions into the GIS in order to verify the detection sensitivity for the GIS and the associated measuring equipment. If the stimulated signal can be measured at the adjacent sensor, the sensitivity verification has been successful for the GIS section between these sensors.

Annex D
(informative)

Calculations related to an internal fault

D.1 Calculation of pressure rise due to an internal fault

The pressure rise in a closed compartment filled with SF_6 due to an internal fault can be calculated according to (D.1):

$$\Delta p = C_{\text{equipment}} \times \frac{I_{\text{arc}} \times t_{\text{arc}}}{V_{\text{compartment}}} \tag{D.1}$$

where

Δp	is the pressure rise (Mpa);
I_{arc}	is the fault arc current ($\text{kA}_{\text{r.m.s.}}$);
$V_{\text{compartment}}$	is the volume of the compartment (l);
t_{arc}	is the arc duration (ms);
$C_{\text{equipment}}$	is the equipment factor.

The value of the equipment factor C shall be demonstrated by the manufacturer by tests on similar equipment.

Formula (D.1) can be used to verify that the pressure will not exceed the type test pressure of the enclosures in case of an internal fault in a gas compartment without a pressure relief device. This is verified if the maximum arc current and arc duration (based on the performance of the protective system) does not cause a pressure rise which exceeds the type test pressure of the enclosures.

Annex E
(informative)

Information to be given with enquiries, tenders and orders

E.1 Introduction

Annex E defines, in tabular format, the technical information to be exchanged between user and supplier.

NOTE Reference to "supplier information" means that only the supplier needs to provide this information.

E.2 Normal and special service conditions

See Clause 2.

		User requirements (see Table 101)	**Supplier proposals**
Service condition	Indoor or outdoor		
Ambient air temperature			
Minimum	°C		
Maximum	°C		
Solar radiation	W/m²		
Altitude	m		
Pollution	Class		
Ice coating	mm		
Wind	m/s		
Humidity	%		
Condensation or precipitation			
Vibration	Class		
Induced electromagnetic disturbance in secondary system	kV		

E.3 Ratings

See Clause 4.

		User requirements	Supplier proposals
Nominal voltage of system	kV		
Rated voltage of system	kV		
Rated voltage for equipment (U_r)	kV		
Rated insulation levels phase-to-earth and between phases Rated short-duration power-frequency withstand voltage (U_d) Rated switching impulse withstand voltage (U_s) Phase-to-earth Between phases Rated lightning impulse withstand voltage (U_p)	kV kV kV kV		
Rated frequency (f_r)	Hz		
Rated normal current (I_r)	A	According single line	
Rated short-time withstand current (I_k)	kA		
Rated peak withstand current (I_p)	kA		
Rated duration of short-circuit (t_k)	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	DC or 50 or 60	
Neutral earthing		Solidly or not solidly	

E.4 Design and construction

See Clause 5.

		User requirements	Supplier proposals
Number of phases			
Single- or three-phase design			
Maximum SF_6 leakage rate	% / year		
Rated filling pressure p_r Circuit-breaker Other compartments	 MPa MPa	 Supplier information Supplier information	
Alarm pressure p_a Circuit-breaker Other compartments	 MPa MPa	 Supplier information Supplier information	
Minimum functional pressure p_m Circuit-breaker Other compartments	 MPa MPa	 Supplier information Supplier information	

		User requirements	Supplier proposals
Design pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Type test pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Routine test pressure of enclosures			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Operating pressure of pressure relief device			
Circuit-breaker	MPa	Supplier information	
Other compartments	MPa	Supplier information	
Internal fault			
Short-circuit current	kA		
Quantity of SF_6 gas of complete GIS at filling pressure	kg	Supplier information	
Quantity of SF_6 gas of the largest compartment at filling pressure	kg	Supplier information	
Maximum permissible gas dew point	°C	Supplier Information	
Number of gas compartments		Supplier information	
Length of longest section for transportation	m		
Weight of the heaviest piece of equipment to be handled during installation on-site	kg		

E.5 Bus ducts

		User requirements	Supplier proposals
Inductance	H/m	Supplier information	
Capacitance	pF/m	Supplier information	
Resistance of enclosure at f_r	Ω/m	Supplier information	
Resistance of conductor at f_r	Ω/m	Supplier information	
Surge impedance	Ω	Supplier information	

E.6 Circuit-breaker

Clause 9 of IEC 62271-100 is applicable.

E.7 Disconnector and earthing switch

Clause 9 of IEC 62271-102 is applicable.

E.8 Bushing

Clause 5 of IEC 60137 is applicable with the following additions:

Outdoor-immersed bushing (see 2.18 of IEC 60137)		**User requirements**	**Supplier proposals**
Type of internal insulation		Gas-insulated or resin-impregnated paper	
Type of external insulation		Porcelain or composite	
Nominal specific creepage distance	mm/kV		
Shed profile		Normal or alternating	
Rated short-duration, power-frequency withstand voltage (U'_d)	kV	As GIS or special	
Rated switching impulse withstand voltage (U'_s)	kV	As GIS or special	
Rated lightning impulse withstand voltage (U'_p)	kV	As GIS or special	
Cantilever test load	N		
Cantilever operation load	N		
Type of line termination		According drawing	

E.9 Cable connection

Clause 9 of IEC 60859 is applicable with the following additions:

		User requirements	**Supplier proposals**
Type of cable		Fluid-filled or dry type	

E.10 Transformer connection

Clause 9 of IEC 61639 is applicable with the following additions:

		User requirements	**Supplier proposals**
Insulated junction between transformer tank and GIS enclosure		Yes or no	

E.11 Current transformer

Clause 10.2 of IEC 60044-1 is applicable with the following additions:

		User requirements	Supplier proposals
Position of current transformer		According single line	
Number and type of cores		According single line	

E.12 Inductive voltage transformer

Subclause 11.1 of IEC 60044-2 is applicable with the following additions:

		User requirements	Supplier proposals
Position of voltage transformer		According single line	
Number and type of secondary windings		According single line	
On-site test voltage	kV/Hz	Supplier information	

E.13 Documentation for enquiries and tenders

Subclause 10.2 of IEC 60044-1 is applicable with the following additions:

		User requirements	Supplier proposals
Single line diagram			
General arrangement drawings of substation layout			
Foundation loading		Supplier information	
Gas schematic diagrams		Supplier information	
List of type test reports		Supplier information	
List of recommended spare parts		Supplier information	

(*Continued from second cover*)

International Standard	*Title*
IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m = 170 kV) — Test methods and requirements
IEC 60859	Cable connections for gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above — Fluid-filled and extruded insulation cables — Fluid-filled and dry type cable-terminations
IEC 61462	Composite insulators — Hollow insulators for use in outdoor and indoor electrical equipment — Definitions, test methods, acceptance criteria and design recommendations
IEC 61639	Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above
IEC 61672-1	Electroacoustics — Sound level meters — Part 1: Specifications
IEC 61672-2	Electroacoustics — Sound level meters — Part 2: Pattern evaluation tests
IEC 62155	Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V
ISO 3231	Paints and varnishes — Determination of resistance to humid atmospheres containing sulfur dioxide

Only the English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc: No. **ETD 08 (5704).**

Amendments Issued Since Publication

Amendment No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices:

		Telephones
Central :	Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110 002	2323 7617 2323 3841
Eastern :	1/14, C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700 054	2337 8499, 2337 8561 2337 8626, 2337 9120
Northern :	SCO 335-336, Sector 34-A, CHANDIGARH 160 022	260 3843 260 9285
Southern :	C.I.T. Campus, IV Cross Road, CHENNAI 600 113	2254 1216, 2254 1442 2254 2519, 2254 2315
Western :	Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400 093	2832 9295, 2832 7858 2832 7891, 2832 7892

Branches: AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.

Printed at Prabhat Offset Press, New Delhi-2